AERONAUTICAL ENGINEERING REVIEW

NOVEMBER 1951

AIRCRAFT: First Jet Carrier Photographic Plane, Navy

F2H-2P Banshee, Produced by McDonnell

ENGINE: Westinghouse J-34 Jet

METERING SYSTEM: Holley Turbine Control

FOR MORE THAN HALF A CENTURY—ORIGINAL EQUIPMENT
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DETROIT

Now Goodyear tires are landing at 250 mph

The new 250 mph dynamometer at Wright Field is shown here with Goodyear Rib All-Weather Tread Tire on test for use on high-speed jet aircraft.

HAVING successfully completed test requirements for landing and take-off in the 240 mph speed range, Goodyear high-pressure airplane tires for jet aircraft are currently under test at 250 mph on the new dynamometer at Wright Air Development Center of the U. S. Air Force.

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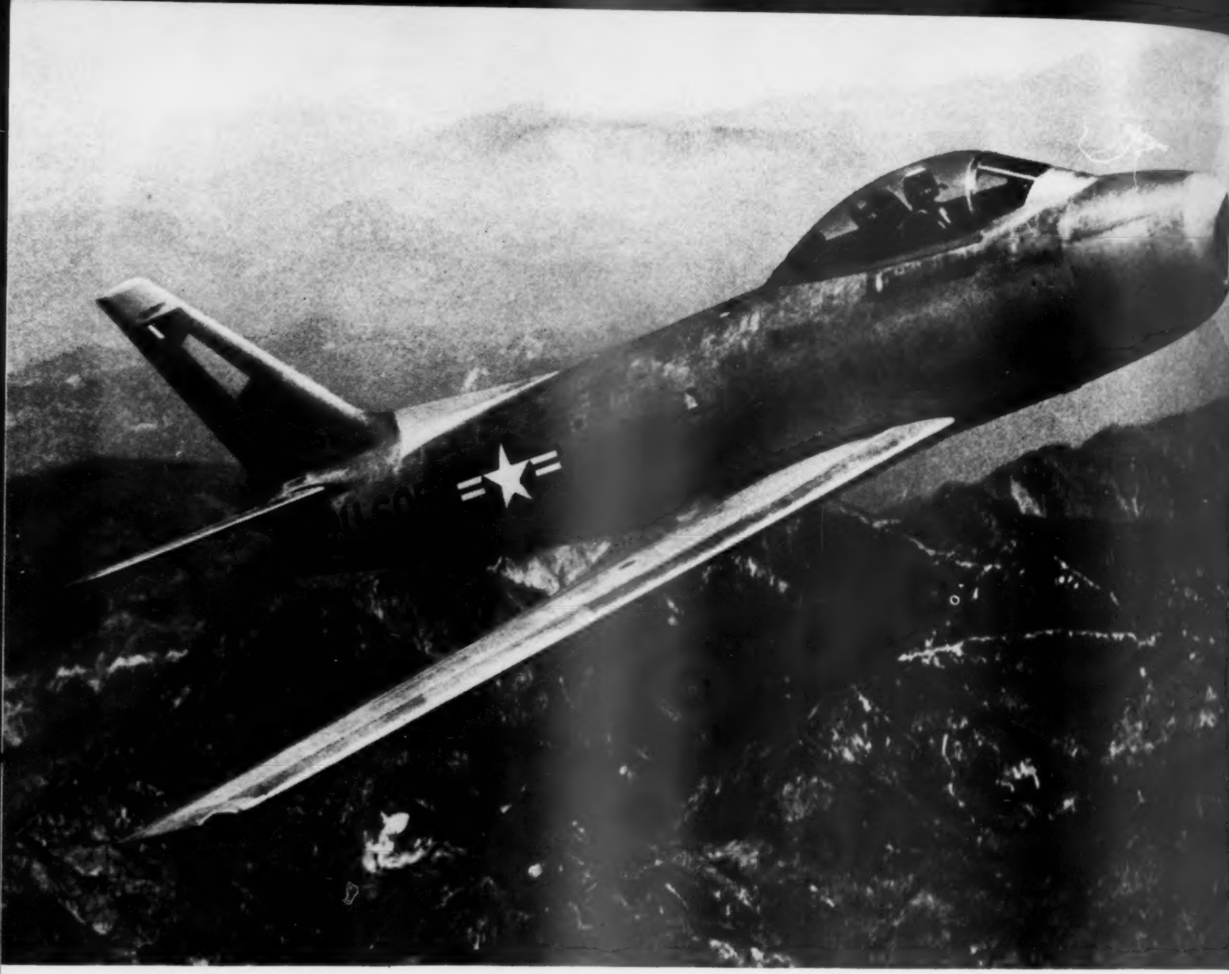
For further information on these tires and other Goodyear Aviation Products—tubes, wheels, brakes, aircraft hose, the Cross-Wind Landing Wheel, electro-thermal Iceguards and Airfoam Super-Cushioning—write Goodyear, Aviation Products Division, Akron 16, Ohio or Los Angeles 54, California.



Cover—The F-94 all-weather fighter-interceptor, manufactured by Lockheed Aircraft Corporation, is an active participant in the Korean war theater. It is armed with four 0.50-cal. machine guns located in the nose.

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AERONAUTICAL ENGINEERING REVIEW

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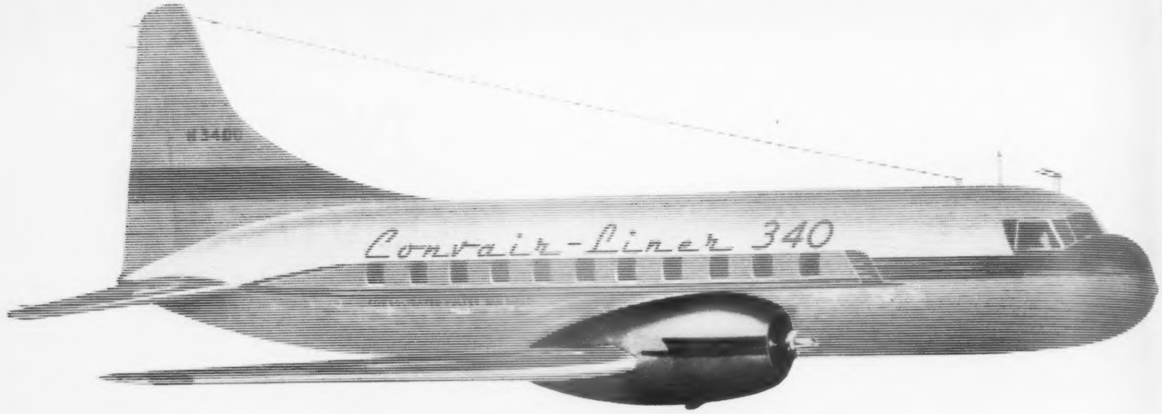
Convair-Liner 340

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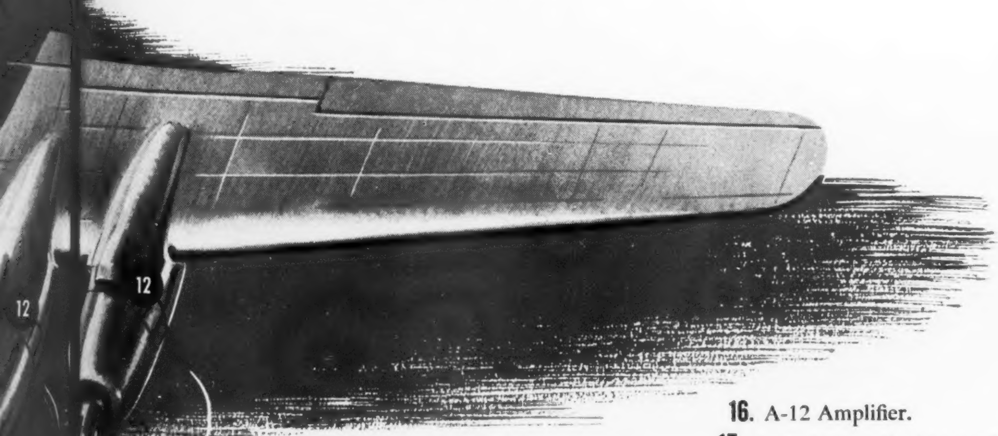

7. Zero Reader Heading Selector.
8. Zero Reader Selector Switch.
9. Zero Reader Control.
10. C-2 Gyrosyn Compass Amplifier.
11. C-2 Gyrosyn Compass Flux Valve.
12. Engine Analyzer Synchronizing Generators.
13. Engine Analyzer Cycle Switch.
14. Engine Analyzer Condition Switch.
15. Engine Analyzer Power Supply-Amplifier.
16. A-12 Amplifier.
17. A-12 Automatic Approach Amplifier.
18. A-12 Vertical Gyro Control.
19. A-12 Gyrosyn Compass Control.
20. A-12 Pilot Engaging Control.
21. A-12 Servo Control.
22. A-12 Rudder Servo.
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25. A-12 Elevator Trim Tab Servo.
26. A-12 Flux Valve.


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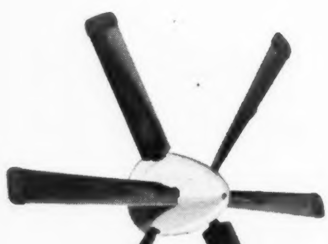
ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

4608

U. S. Navy's A2D Douglas Skyshark equipped with Aeroproducts dual-rotating propeller.



Would You have Signed?

Jefferson, Adams, Harrison, Franklin and the rest did! Because they put the public welfare above every other consideration, their signatures on The Declaration of Independence changed the course of History. Would *you* have signed? Fortunately, most of us will never have to face a decision like that. Yet, daily, your signature does vitally concern the performance and reputation of your planes. Whatever your type of aircraft, your signature on the specifications directly affects thousands of people. A constantly growing number of aircraft designers, manufacturers and airline operators meets this obligation by specifying Eclipse-Pioneer instruments and accessories. Long experience with these products has bred respect for their performance. When your signature is required on a specification sheet, you can conscientiously feel you've chosen the best the field affords, when you indicate Eclipse-Pioneer.

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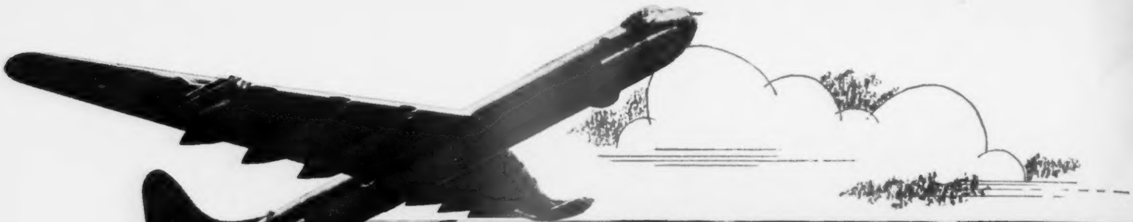

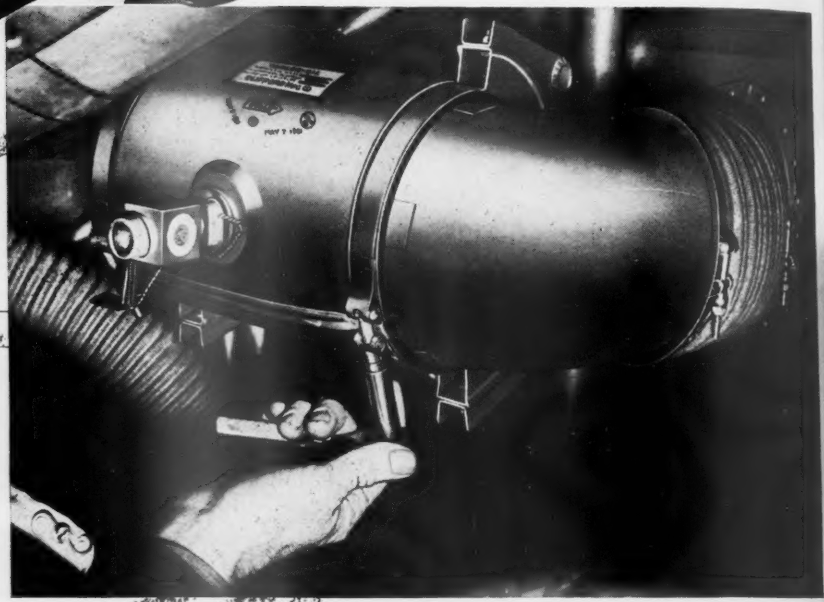

Clifford Feather Weights Cool the Oil in

WORLD'S LARGEST BOMBER, the Convair B-36D, has a 10,000 mile range and a ceiling of over 45,000 feet.

It uses a Clifford oil cooler to get rid of the heat generated in the constant speed drive which links the engine to the 400 cycle alternator. The oil cooler is essential to the proper operation of the unit under the varying conditions of takeoff and flight, and permits the use of a smaller size and lower weight drive.

CONVAIR B-36D BOMBERS

Conventional or jet powered, civilian airliner or world's largest bomber . . . all types of modern aircraft depend on Clifford Feather Weight All-Aluminum Oil Coolers . . . *the only all-brazed type* of oil coolers. Their superior weight-strength ratio is achieved through Clifford's patented brazing method and pre-testing in Clifford's wind tunnel laboratory . . . the largest and most modern in the aeronautical heat exchanger industry. For further details, write Clifford Manufacturing Company, 138 Grove Street, Waltham 54, Mass. *Division of Standard-Thomson Corporation.* Sales offices in New York 17, Detroit, Chicago 1, Los Angeles.

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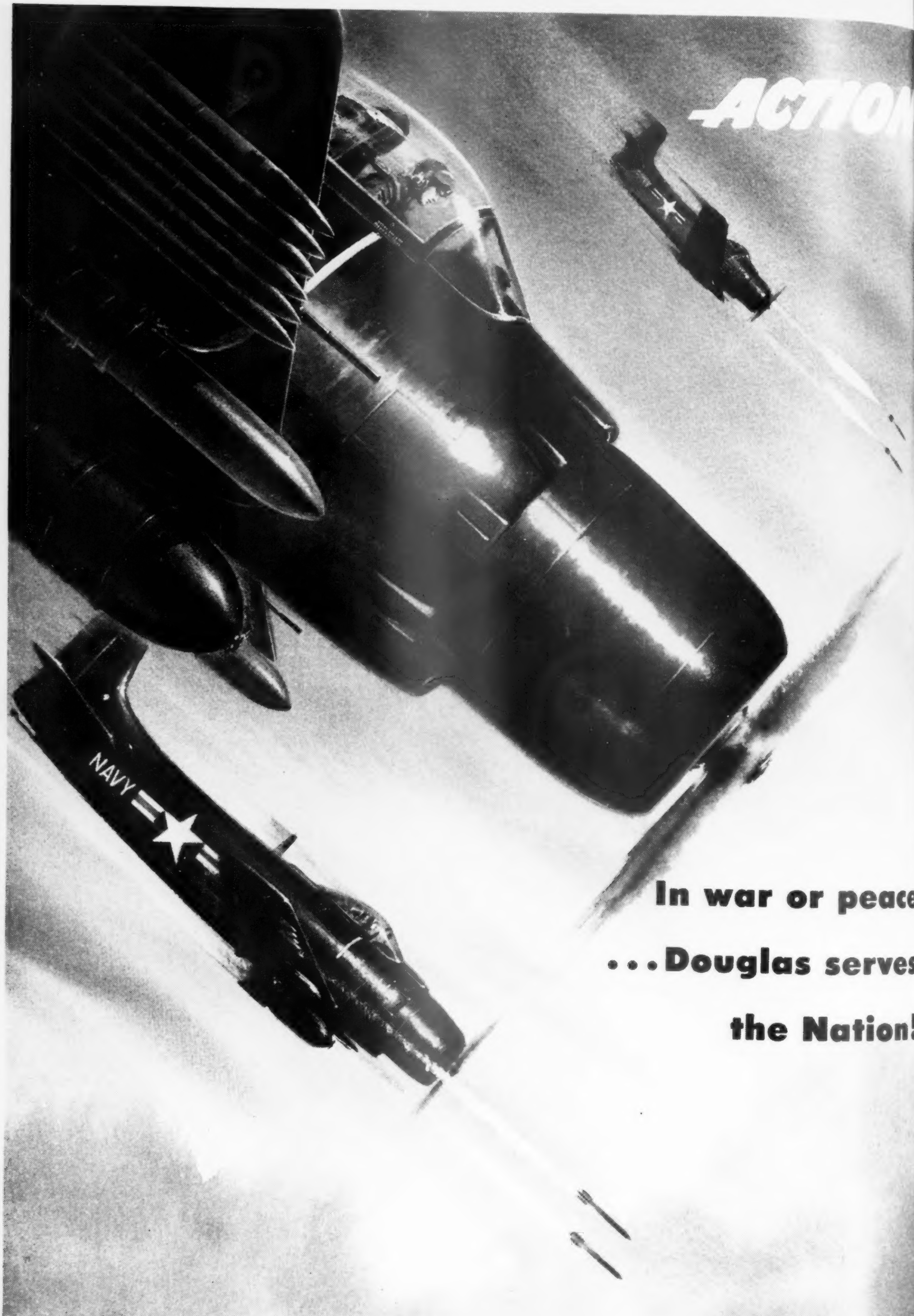

ACTION
NAVY
In war or peace
...Douglas serves
the Nation!

I. A. S. News

A Record of People and Events of Interest to Institute Members

Daniel Guggenheim Park Sold

U.S. Government Purchases Former Daniel and Florence Guggenheim Estate for Use of Special Devices Center

The Daniel Guggenheim Park at Sands Point, Port Washington, L.I., N.Y., the former home of Florence and Daniel Guggenheim which was donated to the Institute of the Aeronautical Sciences by Florence Guggenheim in 1942, has been sold to the U.S. Government for the continued use of the Special Devices Center, Office of Naval Research, U. S. Navy. The Special Devices Center has been occupying these premises since 1945 under lease from the Institute of the Aeronautical Sciences.

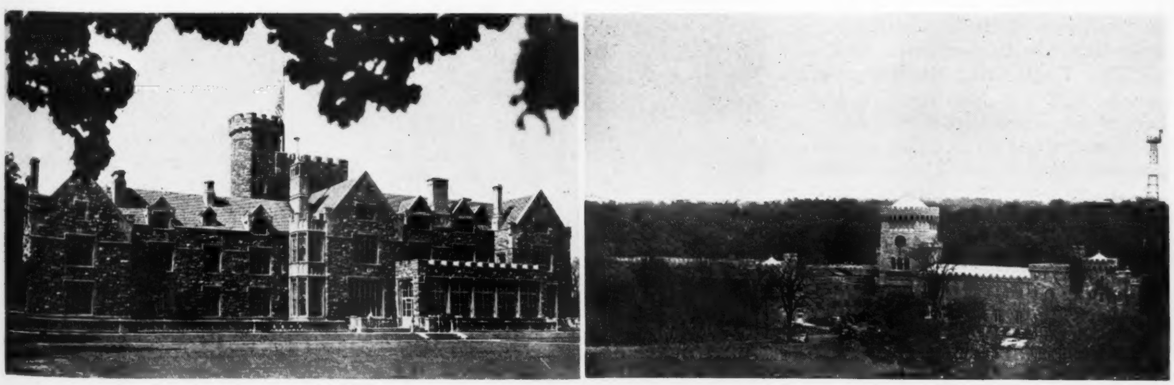
This purchase by the Government was authorized by the action of the House of Representatives in H.R. 7786 which became Public Law 759—81st Congress, Chapter 896—Second Session. Authorization for the permanent establishment of a Special Devices Center at Sands Point was given to the Secretary of the Navy in S. 2440 which was made into Public Law 564—81st Congress, Chapter 294—Second Session.

The Special Devices Center was originally created in April, 1941, as a Special Devices Desk in the Engineering Division of the Bureau of Aeronautics by command of Rear Adm. J. H. Towers, U.S.N., A.F.I.-A.S., now retired but then Chief of BuAer. Rear Adm. (then Comdr.) Luis de Florez, U.S.N.R., F.I.A.S., was assigned in charge of this desk to supervise the experiments and development of special training devices for primary training, navigation training, gunnery training, etc.

In 1943, Special Devices became a Division of BuAer under its Director, Commander de Florez. Two years later, it became a Division of the newly formed Office of Research and Invention of which Captain de Florez was appointed Assistant Chief. In 1946, an Act of Congress established the Office of Naval Research and gave the Center its present title.

The need for Special Devices grew out of the complexity of modern military weapons that per se demanded the utmost of skill and technique in their operation. Prior to World War II, pieces of actual field equipment were used to train the men under supervision. Upon the advent of World War II, this method proved to be too costly in terms of time, money, equipment, and ultimately, lives. Time had proved that the answer to offset much of this great loss lay in producing synthetic training devices that would develop under simulated battle conditions in trainees that instinct necessary to handle operating equipment calmly and efficiently under real battle conditions.

Early in 1942, a small shop and laboratory were established in a remodeled garage building at 610 H St., N.E., Washington, D.C. It is this address that lent Special Devices its wartime trade name, "Project 610." Within 3 years, Special Devices had outgrown its Washington headquarters and another location to serve as a permanent site was sought. In 1945, through the efforts of Admiral de Florez and others, the Daniel Guggenheim Park was selected and a lease for the property accomplished. In



The Daniel Guggenheim Park: *The building at the left is the former residence of Daniel and Florence Guggenheim. It is now occupied by the Special Devices Center, Office of Naval Research, U.S. Navy, as the Administration Building. The structure shown on the right was at one time the stables for the residence, but, since the Navy took over the property, it has become the Engineering Building. On the right of the Engineering Building can be seen the television antennae from which various Naval TV programs are televised.*

May of the following year, the Special Devices Center moved into its new quarters, where, for the first time, adequate space was available for all of its component parts. Through this move, the former Guggenheim mansion became the Administration Building, and the old stables were converted into the Engineering Building.

Today's Special Devices Center incorporates many divisions, branches, and sections, all of which contribute in the initial development and perfection of prototype models of numerous training devices and to their ultimate quantity production under Government contract in the factories of various civilian manufacturers. The diversity of these synthetic training devices is demonstrated by the various names of the research and development sections of the Center: Armament, Navigation and Seamanship, Synthetic Warfare, Electronics, Flight Trainers, Films, Graphics, Topographics, Human Engineering, etc. Some of the research and development necessary to perfect the prototype trainers is carried on through contracts with universities, private industry, and other research groups and through extensive testing and evaluation of the training equipment in the field.

The I.A.S.-Sponsored Applied Mechanics Reviews

The *Applied Mechanics Reviews*, a monthly publication that contains critical reviews of approximately 350 significant articles and a specially prepared survey of progress, is published under the editorship of Martin Goland, M.I.A.S., Midwest Research Institute, by The American Society of Mechanical Engineers. The following organizations are cooperating in sponsoring this publication: Office of Air Research, Midwest Research Institute, American Society of Civil Engineers, Institute of the Aeronautical Sciences, American Institute of Physics, American Mathematical Society, Society for Experimental Stress Analysis, The Engineering Institute of Canada, and The Institution of Mechanical Engineers (Great Britain).

Not an abstract service, the *Applied Mechanics Reviews* provides a concise and critical appraisal of each article or book, in the form of a signed review prepared by an authority on the subject in question. The total number of reviewers is over 800; each person is chosen for his specialized knowledge and skill.

The object of the *Applied Mechanics Reviews*, now in its fourth year of operation, is to provide the engineer with a complete and comprehensive coverage of literature published throughout the world, thus enabling him to keep abreast of the latest developments with a minimum expenditure of time and without the time-consuming and difficult routine of surveying countless original sources each month.

Although many of the books and papers reviewed and evaluated each month are aeronautical in nature, all fields of applied mechanics and related subjects are well covered. Some of the basic subjects covered therein include: aerodynamics, aeroelasticity, compressible flow, flow and flight-test techniques, propellers, fans, experimental stress analysis, buckling problems, structures, properties of materials, mechanics, ballistics, lubrication, fluid mechanics, thermodynamics, and heat and mass transfer.

Individual subscription rate for the *Applied Mechanics Reviews* is $9.00 per year to the members of the various sponsoring societies, which, of course, includes all I.A.S. members. The cost to nonmembers is $12.50 annually. Group subscription rates may be had for $6.50 per subscription, if six subscriptions are mailed to a single address, to six individuals, or to any combination, provided one invoice for all six subscriptions is rendered to a single addressee. Subscriptions should be sent to The American Society of Mechanical Engineers, 29 W. 39th St., New York 18, N.Y.

National Conference on Industrial Hydraulics

The Seventh Annual National Conference on Industrial Hydraulics is scheduled to be held on November 8-9 at Chicago's Sherman Hotel. The 2-day meeting, under the sponsorship of the Graduate School of Illinois Institute of Technology and Armour Research Foundation of Illinois Institute of Technology, will be devoted to the presentation of technical papers by authoritative speakers on the latest developments in the industrial hydraulics field.

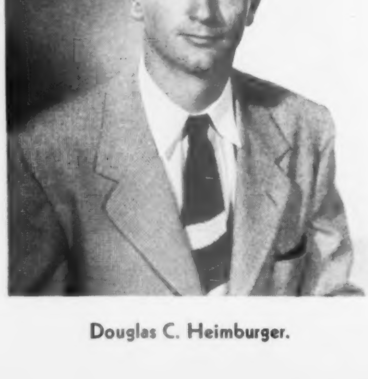
Cooperating societies are the local sections and chapters of the American Institute of Chemical Engineers, American Society of Agricultural Engineers, American Society of Civil Engineers, American Society of Lubricating Engineers, American Society of Mechanical Engineers, Illinois Society of Professional Engineers, Institute of the Aeronautical Sciences, Society of Automotive Engineers, and Western Society of Engineers.

Necrology

Douglas Corbett Heimburger

Douglas Corbett Heimburger, M.I.A.S., was killed the evening of September 1 in the mid-air collision of two B-47 Stratojet bombers during a routine production test flight near Wichita, Kan. He was 31 years old.

Born in Weisein, China, of missionary parents, Mr. Heimburger attended secondary schools in St. Louis and Springfield, Mo., and was graduated from Drury College with a B.S. degree. He had been granted his M.S. degree in Aeronautical Engineering in 1948 by Purdue University.



Douglas C. Heimburger.

Since Mr. Heimburger first began flying in 1939 under the auspices of the Civil Pilots Training Program, he had accumulated many thousands of hours of flying time in over 100 different types of military and civilian aircraft. During World War II, he was Flight Instructor and Ground School Instructor at Randolph Field, Tex., and Engineering Test Pilot at Wright Field, Ohio. Prior to coming to Boeing Airplane Company in 1948 as an Engineering Test Pilot, he taught a course in flight-test methods and instrumentation to senior engineering students at Purdue and was a Flight Instructor at Purdue's School of Aeronautics. Mr. Heimburger, who was Chairman of the Wichita Section at the time of his death, was a B-47 Project Pilot at Boeing's Wichita Division.

Mr. Heimburger is survived by his wife, Harriet, and two children, Cynthia, aged 5, and Bruce, aged 2.

Dr. Clarence Henry Powell

Dr. Clarence Henry Powell, M.I.A.S., died on May 13 at the age of 61.

Dr. Powell, who was born in Worcester, England, received his B.Sc. degree in Mechanical Engineering from the University of Birmingham, England, in 1912. The University of Michigan granted him an M.S. degree in 1932 and a Sc.D. degree in Mechanical Engineering in 1934.

Intimately associated with aeronautics since 1914 when he went to work for the National Physical Laboratory in England as Scientific Staff Member concerned with the wind-tunnel laboratory and aerodynamic research, Dr. Powell specialized in the fields of the advanced analysis of mechanical engineering, vibrations and stresses, and turbo machinery. He resigned as Aerodynamicist with Sopwith Aviation Company, England, in 1920 to accept a position as Aerodynamics Instructor at Massachusetts Institute of Technology. For 5 years, he was Head of the Aeronautical Department at the University of Detroit. Since 1926, he was Research Engineer with Hudson Motor Car Company, University of Michigan, Carrier Corporation, and Ranger Aircraft Engines Division of Fairchild Engine and Airplane Corporation.

Robert Louis Segal

Robert Louis Segal, M.I.A.S., passed away earlier this year at the age of 40.

Born in Eveleth, Minn., Mr. Segal attended the Eveleth Junior College and the University of Minnesota, graduating from the latter institution in 1933 with a Bachelor's degree in Aeronautical Engineering.

His first employment was as an Inspector with the Minnesota State Highway Department. He remained there for 7 years, leaving in 1941 to accept a position with North American Aviation, Inc., as Stress Analyst. A short time later, he became Structures Engineer on engine mounts, control systems, landing gears, and wings. In 1945, he was promoted to Supervisor of Landing Gear Structures in North American's Structures Department.

Raymond Ware

Raymond Ware, I.A.S. Founder Member and Associate Fellow, passed away the first of this year. He was 67 years old.

A native of Boston, Mass., Mr. Ware attended the Massachusetts Institute of Technology and was graduated from there in 1907 with a B.S. degree in Naval Architecture.

Mr. Ware had been identified with the aeronautical industry since 1915. For 2 years, he was Sales Manager and Engineer for Thomas Brothers Aeroplane Company. In 1917, he went with Thomas-Morse Aircraft Corporation and during the next 15 years held successively the positions of Sales Manager, Secretary, and Vice-President. Although he established himself as a Consulting Engineer in 1932, he devoted a considerable amount of the interim time to his own inventions, especially to the development of a sleeve-type aircraft engine.

News of Members

▶ **A. B. Asch** (M.), Chief Engineer, Asch Equipment Company, has moved with his company from Long Island City, N.Y., to Dayton, Ohio.

▶ **Professor Emerson W. Conlon** (F.), who served for a time as Technical Director of the Arnold Engineering Development Center, Tullahoma, Tenn., returned to his post as Chairman, Department of Aeronautical Engineering, University of Michigan, at the beginning of this academic year.

▶ **Willy Ley** (M.), Research Engineer, Washington Institute of Technology, is Technical Adviser on rockets and the like for a comic strip entitled "Tom Corbett—Space Cadet." It is being syndicated through the Field Enterprises and began its run in the New York *Herald-Tribune* on September 9.

RECEIVES NEW APPOINTMENT

Dr. Antonio Ferri (A.F.), who has been working in supersonic aerodynamics since the early 1930's, has been appointed Professor of Aerodynamics at the Polytechnic Institute of Brooklyn. In addition to his professorial duties, he will carry out an intensive research program in aerodynamics under the sponsorship of various branches of the U.S. Armed Forces. Dr. Ferri came to this country from Italy in 1944 to partake in the war effort under the auspices of the Office of Strategic Services and was assigned to N.A.C.A.'s Langley Aeronautical Laboratory, Va. He resigned his post with N.A.C.A. as Head of the Gas Dynamics Branch to accept his present position.

▶ **Dr. Leo Schapiro** (M.), of Douglas Aircraft Company, Inc., has been appointed to the recently formed Alternate Steel Panel of Aircraft Industries Association of America, Inc. This particular panel was established to handle the engineering aspects of substitutes and alternates.

▶ **John Stack** (F.), Langley Aeronautical Laboratory, N.A.C.A., Va., has been selected to serve as a member of the Scientific Advisory Council of the Picatinny Arsenal. The purpose of this council is to assist the arsenal in its research and development program for ammunition items.

▶ **Sir Henry Tizard** (H.F.) is giving up his post as Chairman, Advisory Council on Scientific Policy, England. Sir John Cockcroft will succeed him next March.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of I.A.S. members. All members are, therefore, urged to notify the News Editor of changes as soon as they occur.

David F. Berry (M.), Process Analyst "A," Georgia Division, Lockheed Aircraft Corporation. Formerly, Project Engineer, Structures Test Group, Wichita Division, Boeing Airplane Company.

Lieutenant (j.g.) Lawrence G. Body, U.S.N. (T.M.), Jet Training Unit One, Naval Auxiliary Air Station, Kingsville, Tex. Formerly, Naval Cadet, Naval Air Station, Pensacola, Fla.

Dr. Walter M. Boothby, M.D. (A.F.), Consultant in Aviation Medicine, Lovelace Foundation for Medical Education and Research. Formerly, Research Consultant, Aviation Medicine, Aeronautical Medical Laboratory, Institute of Physiology, University of Lund, Sweden.

Joseph R. Brom (T.M.), The RAND Corporation. Formerly, Ordnance Research No. 1, Museum of Science and Industry, University of Chicago.

Captain Richard J. Cerny, U.S.A.F. (M.), Design and Development Officer, 1002nd Inspector General Squadron, Directorate of Flying Safety Research, Nor-

(Continued on page 66)

I.A.S. President Richardson sums up the accomplishments of the Third International Conference at Brighton.

Editorial

Fait Accompli

The Third International Conference has come and gone. For those of us who were fortunate enough to attend the sessions in Brighton and to participate in the programs of the following week, it was an unforgettable experience. For the two societies it marked another milestone on the road of international cooperation in the field of the aeronautical sciences.

In his closing remarks at Brighton, I.A.S. President Richardson summed up the situation very clearly. He pointed out that the first two conferences (London, 1947, and New York, 1949) had been somewhat experimental. None of us then knew what might be expected from joint meetings on both sides of the Atlantic. But based on the lessons learned in the first two meetings, the Third marked the beginning of a new cycle, a pattern whose permanence could not be questioned. Its success guaranteed a continuation of exchanges of this sort between the world's two major societies for years to come. There was no room for doubt in anyone's mind that a great precedent had been established and that a tradition was in the making.

Except to express again our thanks to The Royal Aeronautical Society and to Laurence Pritchard for the extraordinary courtesies that were extended to all of us who attended the meeting, we will not go into the details here of what was done or what was said. The next issue of the REVIEW will be devoted entirely to a report of the meetings and to various aspects of the programs. It will carry also full pictorial treatment of the many events and the people who attended them. Such records will serve two purposes. They will bring back many pleasant memories for those who were with us in England, and they will perhaps create a sense of regret among those who could not attend, coupled with a resolution to participate in future conferences of the two societies on whichever side of the Atlantic they occur.

It goes without saying that plans for future meetings were discussed by officers of both groups. It is too early now to pin-point time or place, but, unless the world comes apart at the hinges in the interim, there will certainly be a return engagement in the United States some time in 1952. Some suggestions were heard that the Fourth Conference might well be set up in connection with our regular Summer Meeting in Los Angeles in the summer of 1952. Circumstances will, of course, alter cases, but, in any event, it is a program that might well be given attention by the Councils of both groups as time goes on.

No editorial comment at this stage would be complete without some mention of two associated events that took place immediately following the Brighton Sessions.

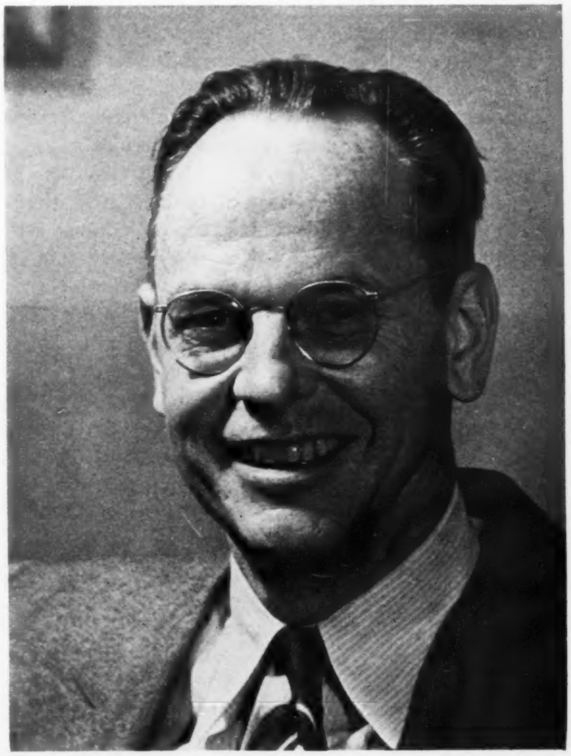
The Annual flying and static display of the Society of British Aircraft Constructors is an event marked on most aviation calendars. This year it was particularly noteworthy because the British high-speed experimental programs have just about come to full flower. Again, space does not permit full comment here, but to say that those of us who viewed the excellent displays of aircraft and components on the ground or tried to twist our necks fast enough to watch the "fly-past" of aircraft at near sonic speeds were impressed would be gross understatement. We can only hope that the reports that undoubtedly reached the Kremlin in the following days made an equally deep impression.

The other event of note was the Wilbur Wright Memorial Lecture. Arthur Raymond's simple, sensible, straightforward approach to his "Well Tempered Airplane" gave us all something to think about. It is safe to say that few other Americans who have stood on their feet before British audiences have ever made a more profound impression. In days when there is a great deal of very "fuzzy" thinking on both sides of the Atlantic as to the future of high-speed transport, his clear and factual treatment will long stand as a significant milepost on the road to reality. Every member of the Institute may well be proud of the job that was done in London by one of our Past Presidents.

Taking all the events of the weeks of September 3–14 into consideration, a new high point was reached in Anglo-American aeronautical relations. It augurs well for the future of the two great English-speaking nations that a firm pattern of such meetings has now been established for all the years ahead.

Paris, September, 1951 S. P. J.

Arthur E. Raymond—1951 Wright Lecturer



Ceramics and Special Alloys

A Metallurgical Investigation at Elevated Temperatures

WILSON G. HUBBELL*

Ryan Aeronautical Company

FIG. 1. Mr. Hubbell is shown arranging test setup for heating ceramic coated test headers to 1,700°F. prior to thermal shock test.

As a result of a series of unique tests conducted with ceramic coated exhaust system components, the Ryan Development Laboratories have shown that the ceramic will provide the protection necessary to extend the life of 19-9DL stainless steel at elevated temperatures encountered in aircraft service. No deterioration by oxidation, carbon absorption, or corrosion attack was evidenced in the components protected by the ceramic coatings for test periods running to 1,623 hours.

This extended life is important both from a standpoint of better service in aircraft engine exhaust systems and as a substantial aid in the conservation of critical elements that are in short supply and which are generously used with corrosion-resistant alloys. It means that the so-called "luxury" class of alloys can, in many cases, be supplanted by cheaper alloys when given the benefit of life-extending ceramic coatings.

A thermal shock resistance test showed that the ceramic coating, Bureau of Standards No. A-417, is not affected by thermal shock as encountered in exhaust system service at any temperature between −75°F. and 1,700°F. and that it will stand a surprising amount of mechanical impact without sustaining damage.

In order to obtain the most useful test data, Ryan manufactured a number of exhaust system components not only of ceramic coated 19-9DL but also of a variety of uncoated alloys and arranged with Pan American World Airways for these components to be used on the engines of Boeing 377 Stratocruiser aircraft engaged in transpacific flights.

The Pan American Stratocruisers were selected because they offered the best combination of advantages desired in the experiments. Their four 3,500 hp. Pratt and Whitney engines are the largest piston-type engines in use on aircraft, and the transpacific flight run developed the maximum test hours within a specified time because of the long distances flown. It was deemed advisable to take advantage of these optimum conditions to make and test a variety of materials, in addition to the ceramic coated metals.

The components chosen for these flight tests were "headers," which channel the hot gases from the cylinders to the collector ring and are the hottest operating part of the exhaust system. Through the cooperation of Pan American World Airways, the test headers were removed from the engines at specified intervals, returned to Ryan for metallurgical examination, and replaced on the engines for further flight experience.

The operation of stainless steel exhaust systems on large aircraft engines is considered to be one of the most tortuous applications for corrosion-resistant alloys because of the elements involved. These thin-walled structures must withstand continual blasts of high-velocity exhaust gases, severe vibration, and frigid atmospheric conditions and must operate for extended periods at temperatures as high as 1,800°F.

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* Chief Metallurgist.

For the tests, Ryan production departments fabricated exhaust headers of the following materials and labeled each by special name plates as follows.

19-9DL stainless steel, 0.043-in. gage, with ceramic coatings on both interior and exterior
19-9DL stainless steel, 0.043-in. gage with ceramic coatings on interior only
19-9DL stainless steel, 0.043-in. gage uncoated (three control headers)
17-14 CuMo, 0.043-in. gage, uncoated
310 Mod. stainless steel, 0.043-in. gage, uncoated
310 with columbium added, 0.043-in. gage, uncoated
Inconel X, 0.043-in. gage, uncoated
N-155, 0.043-in. gage, uncoated
Hastelloy C, 0.043-in. gage, uncoated

Tests consisted of metallographic examinations, photomicrographs, spectrographic analyses, microhardness readings, and dial gage micrometer observations. Test headers were removed from the aircraft at intervals of approximately 650 hours, 1,000 hours, and between 1,234 and 1,623 hours. Headers were installed on the same cylinder banks of the Pratt and Whitney engines, row B. The wear bands of each header were sawed off, and test samples were taken from the header bodies at the hottest areas adjacent to the wear bands. New wear bands were welded on, and the test headers were returned to service for further hours of actual flight test.

After 650 hours of service with the engines of the PAA Stratocruisers, the test headers that were fabricated of 19-9DL stainless steel were removed and brought to the Ryan Development Laboratories for examination. The ceramic coated 19-9DL headers were compared with those that were not coated in these metallographic examinations. It was found that the ceramic coatings had prevented the occurrence of oxidation, carbon absorption, and corrosion attack and had successfully protected the surfaces of the headers. For the first time in Ryan experience, an examination of exhaust header sections with 650 hours disclosed no signs of deterioration brought about by service conditions.

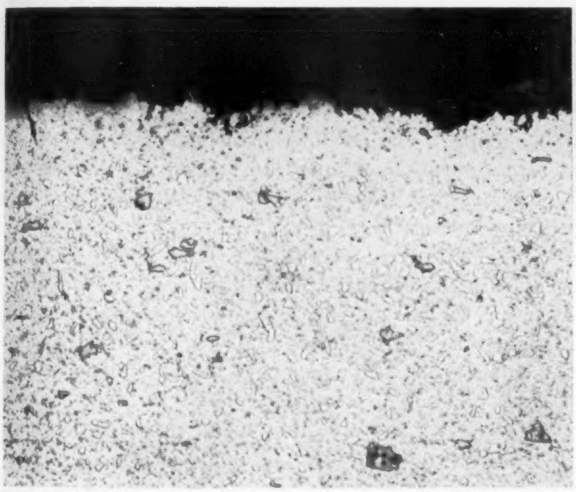


Fig. 2.

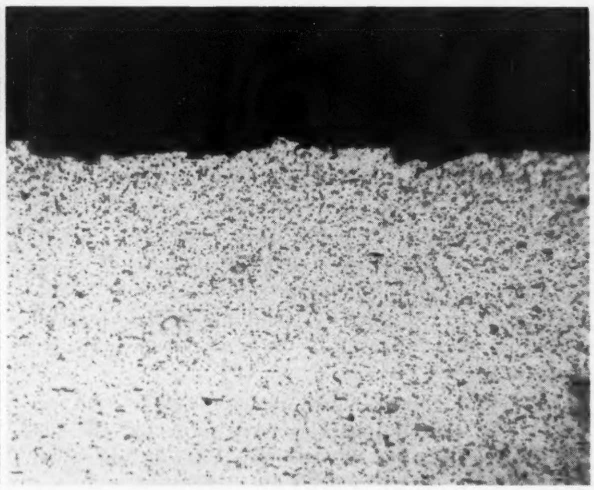


Fig. 3.

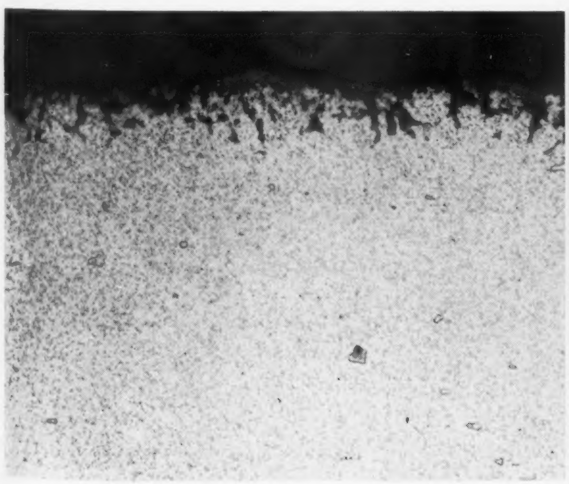


Fig. 4.

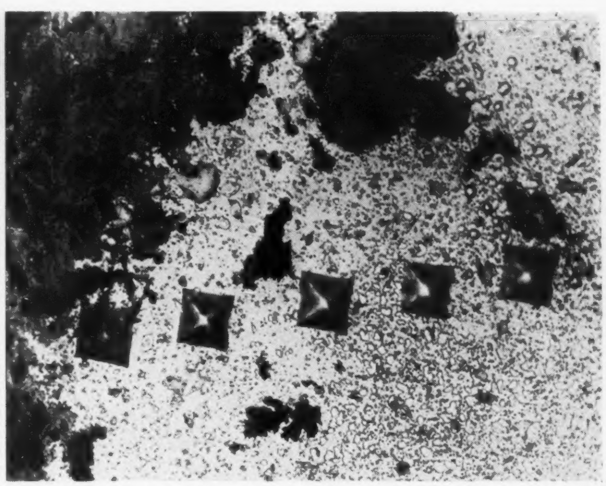


Fig. 5.

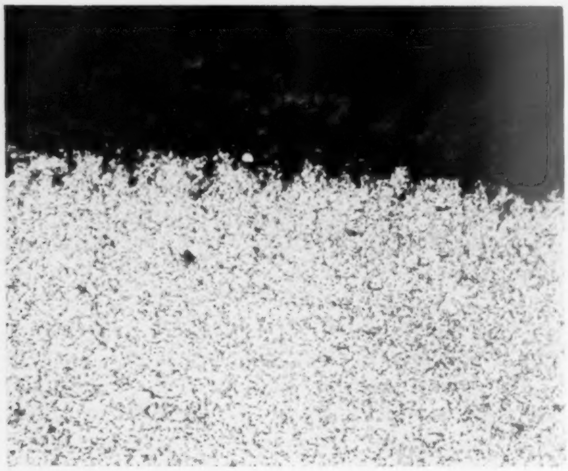


Fig. 6.

19-9DL

No reduction in gage thickness (0.045 in.) was found in the header coated on both sides. Some reduction (0.003 in.), due to scaling on the exterior, was found in the header coated on the interior only. The uncoated header was reduced in thickness by 0.008 in. The ceramic coatings were applied in thicknesses of between 0.001 and 0.002 in.

A photomicrograph (Fig. 2) which was taken at the hot zone, interior, of the header coated on both sides, shows a definite white area lying immediately under the surface of the ceramic material that has been decarburized. Fig. 3, which was taken of a ceramic coated header not tested, does not exhibit this characteristic. Therefore, it is the result of the conditions experienced in the test.

Fig. 2 also shows a sigma formation along with carbide. The ceramic coatings have protected the surfaces. The interior of this header was extremely smooth. The green color of the ceramic coating had changed to black in appearance. A sample of this black coating, when subjected to spectrographic analysis, indicated that it contained the same ingredients as the original green coating—showing that the ceramic material had not been removed but merely changed in appearance.

Fig. 4 was taken of the exterior of the 19-9DL header that was coated only on the interior and shows considerable scaling effect.

The photomicrograph (Fig. 5) shows the surface of the 19-9DL test header, coated on the interior only, which was polished to determine the hardness of light etching zone at the surface. Hardness impress shown represents an actual depth of about 0.0005 in. below surface and gave a hardness reading of 20.5 Rockwell C at the surface and an average interior hardness of 25.0 Rockwell C. The header coated on both sides exhibited a hardness of 19.1 Rockwell C at the surface with an average interior hardness of 23.5 Rockwell C.

Observation and experience in the Ryan Development Laboratories have shown that much of the deterioration of unprotected headers has been due to high rates of carbon absorption with resultant surface embrittlement. In all previous exhaust headers, examined after 650 hours of service, there has been a definite increase in carbon content due to carbon absorption and a high rate of oxide absorption into the grain structure. The ceramic enameling prevents this carbon absorption, eliminates oxidation, and inhibits corrosion attack, thus greatly extending the life of such component parts.

Fig. 6, taken of 19-9DL header, uncoated, after 1,269 hours, shows a typical "salt and pepper" structure of carbide and sigma which is characteristic of the structure after 400 hours of service life. There is some oxide solution at the surface of the material and a moderate build-up on the surface. Aside from the tendency to absorb carbon, the time factor makes little change in the general structure of this material.

Spectrographic analyses of the test headers that were coated with ceramics, after 1,234 hours, showed that

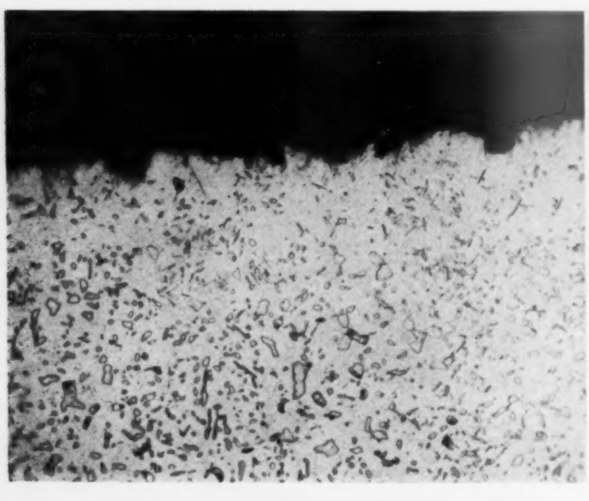


Fig. 7.

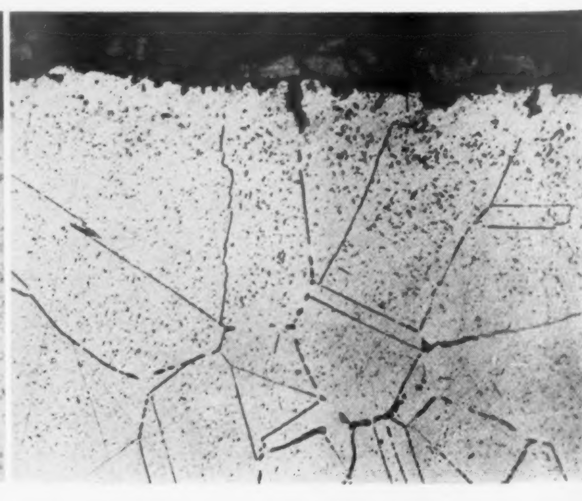


Fig. 8.

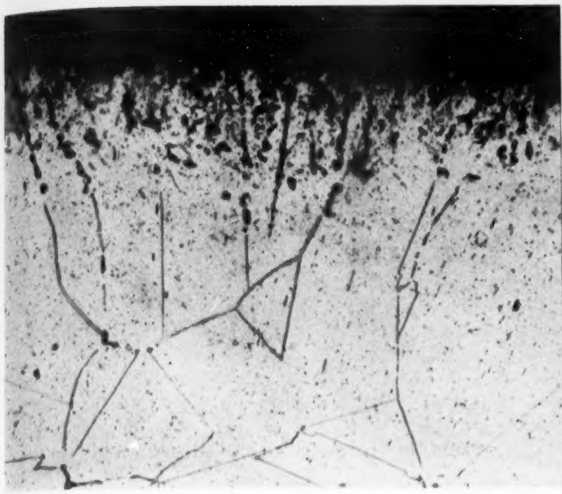


FIG. 9.

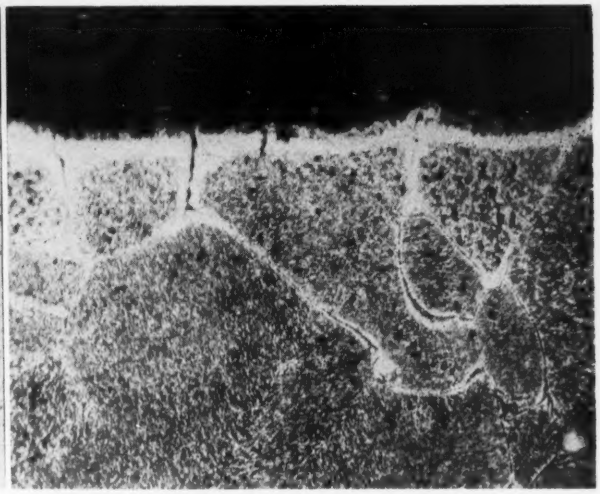


FIG. 10.

the ceramic coatings were still present and protecting the surfaces from oxidation. On the exterior surface of the header coated only on the interior with ceramic, there is some oxide development, although excessive deterioration has not yet been encountered.

Examinations of the alloys, other than the 19-9DL stainless steels that were placed on test, developed the following information.

310 WITH COLUMBIUM

The test header fabricated from 310 with columbium added seems to be in better condition than the other uncoated headers after 1,368 hours of test, because there is little evidence of metal loss due to oxide. Fig. 7 shows a slight tendency towards decarburization. There has been no grain boundary precipitation. However, there are large islands of sigma interspersed with small particles of carbide. The sigma formation is not continuous and will probably leave the material in a relatively ductile condition similar to 19-9DL. It is interesting to note that the sigma formation in 19-9DL does not attain as large a particle size as in 310 Columbium.

310 MOD.

Fig. 8, a photomicrograph taken of the standard 310 Mod. stainless steel header, hottest area, interior, after 1,098 hours of test, indicates a large grain structure with carbides along the grain boundaries. Also, at the grain boundaries, there is some spheroidal sigma. Within the grains, both spheroidal and needle sigma have formed. Some oxide penetration has begun to develop at the juncture of the grain boundaries with the surface of the metal.

Later examinations of the 310 Mod. test header, made after 1,623 test hours, indicates a progressively deeper grain boundary penetration due to oxidation and corrosion. Fig. 9 exhibits this trend along with a heavier development of sigma along the grain boundary, as well as carbide precipitation. Some areas, not shown, indicate even more severe cases and greater depths of penetration along grain boundaries. In all probability, the material would exhibit brittle characteristics in a bend test.

INCONEL X

Fig. 10 was taken of the Inconel X header after 1,385 hours of test. It displays an intergrannular penetration probably caused by corrosion resulting from the alteration of the grain boundaries, either by addition or loss of some constituents. The balance of the structure is in a severely overaged condition. The exterior of the header presents a smooth appearance with little oxidation.

HASTELLOY C

Fig. 11 illustrates the structure of the Hastelloy C header taken after 1,234 hours of test. This microstructure shows a condition of extreme overage, to-

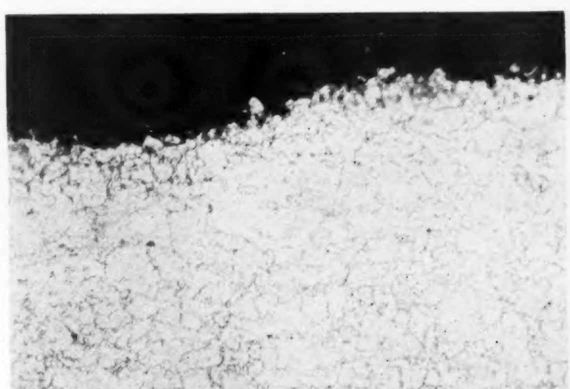


FIG. 11.

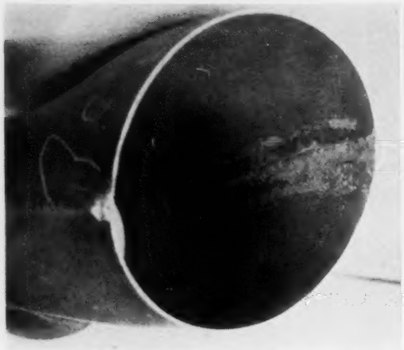


FIG. 12.

FIG. 13.

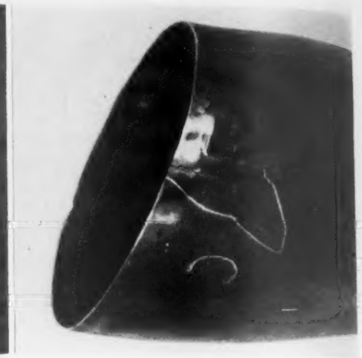


FIG. 14.

gether with heavy precipitate along the grain boundaries. This has resulted in making the material extremely brittle. On a bend test, it fractured without taking a permanent set, which demonstrates the complete absence of ductility. This brittle condition made it necessary to remove this part from further service testing. Upon parting the wear band from the header to obtain a metallographic specimen, the part cracked spontaneously as shown in Fig. 12. This crack started from a defect that had existed under the wear band but was in a dormant state, as evidenced by being completely filled with oxide. (Note photomicrograph, Fig. 13.) In addition, a state of erosion had set in adjacent to the weld seam in the hottest operating part of the header, which is opposite to the port leg, as shown in Fig. 14. From a safety standpoint, it was not advisable to return this header to service even though a new wear band could have successfully been welded to the part.

17-14 CuMo

The test header fabricated from 17-14 CuMo alloy was removed from service after 472 hours because of excessive thinning as shown in Fig. 15. Metallographic examination indicates that this thinning was due to intergrannular corrosion at the surface of the material and high temperature oxidation.

FIG. 15.

The wear band had a thickness of 0.064 in. where least affected by oxidation and corrosion and measured from 0.032 in. down to the formation of a knife edge at the area most affected. The body of the stamping had a thickness of 0.036 in. at the coolest operating portion and a thickness of 0.030 in. where impingement of exhaust gases and high temperature appeared to be greatest. At the edge of the top of the weld seam, a measurement of 0.032 in. was obtained, and 0.03125 in. away from the weld, 0.027 in. was the thickness.

Fig. 16 shows an advanced condition of intergrannular corrosion in the hottest operating area of the wear band.

Fig. 17, taken at the hottest operating area, at point of gas impingement, shows a condition of heavy carbide precipitation, carbon absorption with oxide solution, and intergrannular attack along grain boundaries.

Fig. 18 shows the 17-14 CuMo material prior to testing with area free from carbide precipitation along grain boundaries.

The test header fabricated of 17-14 CuMo does not have the ability to withstand the high temperatures at which this part operates. Oxidation and carbide precipitation lead to rapid deterioration during service under the conditions peculiar to this application. It is seldom that intergrannular corrosion is observed in materials designed for conducting gases at elevated temperatures. Most materials, even though containing high percentages of unstabilized carbon, develop a tightly adherent film that excludes the product causing corrosion. In the case of 17-14 CuMo, the material developed a loose scale that did not prevent the attack by corrosive media.

N-155

Fig. 19 was taken of the header made from N-155, after 1,098 hours, on the hot interior surface. This photomicrograph shows heavy precipitation agglomeration within the grain. The surface of the material shows a white decarburized layer. This heavy precipitation tends to reduce the ductility. A 35° to

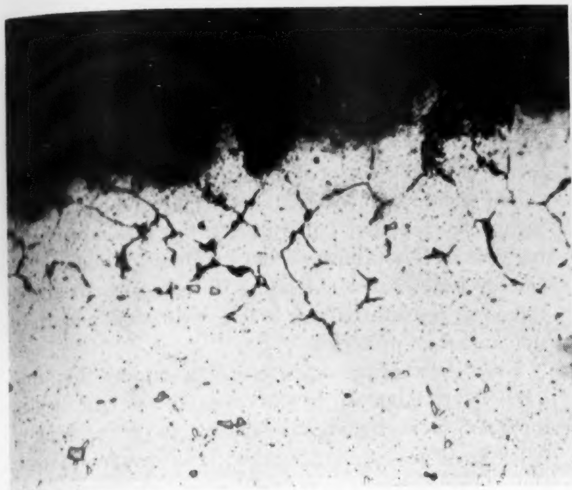


FIG. 16.

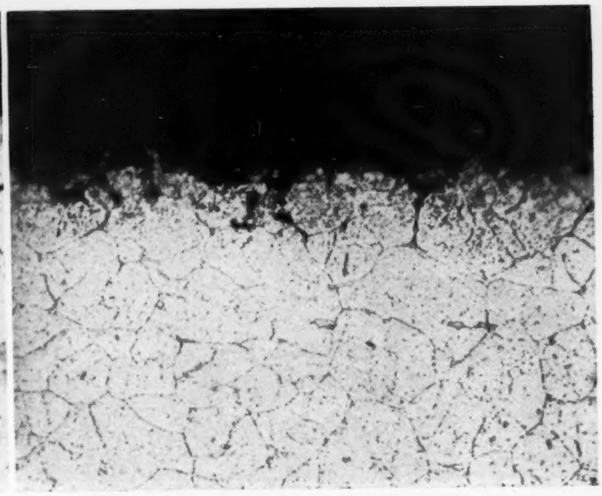


FIG. 17.

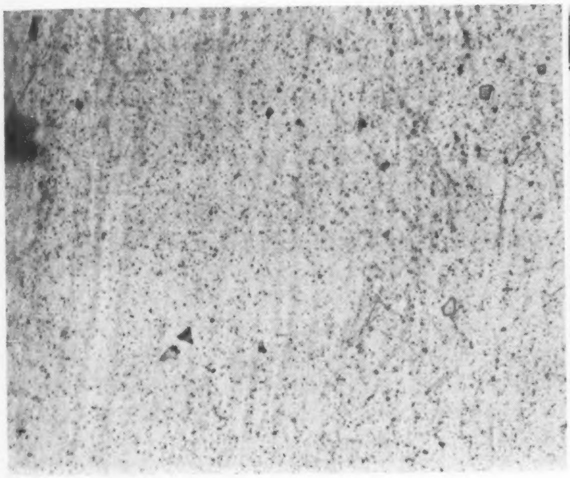


FIG. 18.

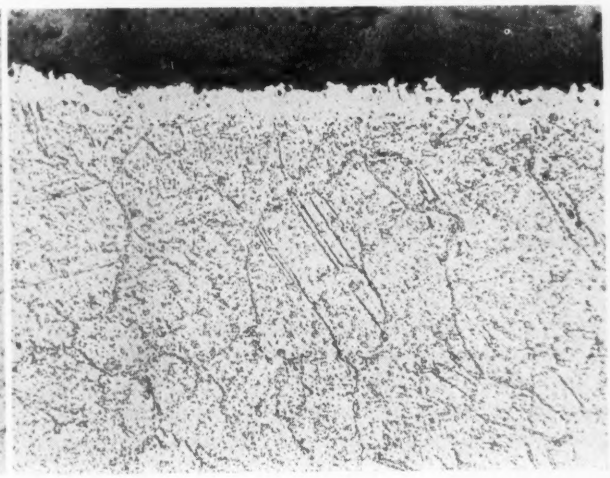


FIG. 19.

40° bend results in a brittle fracture. After 1,623 hours of test, the N-155 header exhibited a condition of pitting which was the result of high velocity blow-by of exhaust gases. (See Fig. 20.)

THERMAL SHOCK TEST

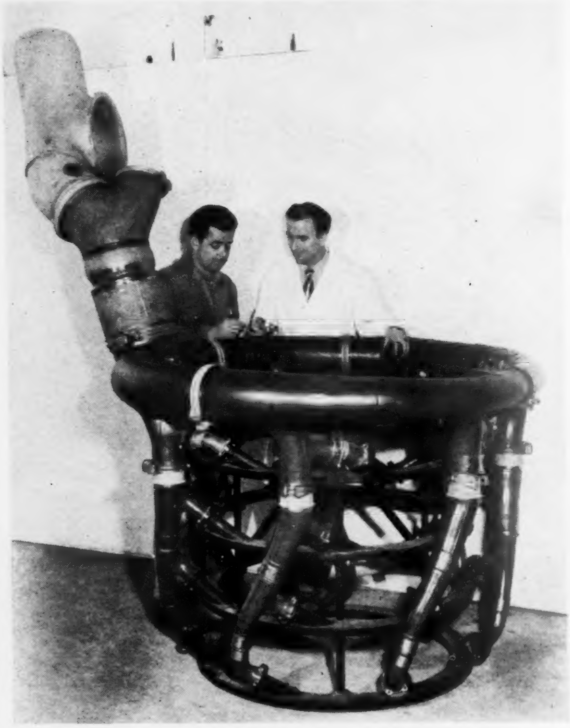
A special test was conducted to ascertain the thermal shock resistance of the A-417 ceramic coating, as applied to the Ryan exhaust system headers. In this test, a number of ceramic coated headers was given the following temperature treatment:

First run—These specimens were cooled overnight to −60°C. (76°F.) with dry ice in a refrigerator for 18 hours and then were heated with a special burner to 1,700°F.

Second run—The specimens were cooled to −56°C. (−68.8°F.) for four hours and then were heated to 1,500°F.

Third run—The specimens were cooled to −57°C. (−70.6°F.) for 19 hours and then were heated to 1,600°F.

FIG. 20.



Mr. Hubbell (*right*) inspects the complete ceramic coated exhaust system that Ryan builds for the engines of the Boeing 377 Stratocruiser.

One specimen from each of the above test runs was dropped 6 ft. on a concrete floor when cold and hot for impact shock test. Handling time was limited to 10 sec., and sufficient time was allowed to produce complete heat saturation. After all test runs, there were no cracks, chips, or other damage to the ceramic coating. The ceramic coating stands up under severe shock by hot and cold temperatures and does not appear to be susceptible to damage from mechanical means at extreme temperatures.

Conclusions

The presence of the ceramic coating on the 19-9DL test headers successfully protected these headers from deterioration from oxidation, carbon absorption, and corrosion attack for the period of the tests and under operating temperatures upward to 1,800°F. Additional and continued testing is being conducted by the Ryan Development Laboratories, but it is now becoming definitely established that ceramic coatings are decidedly beneficial in extending the life of the heat- and corrosion-resistant alloys where oxidation and corrosion are major problems.

Since the ceramic coatings are extremely thin, from 0.001 in. to 0.002 in. in thickness, the weight increase involved is negligible, amounting to 2 per cent on 0.065-in. gage. In application, it is simpler to apply thin coatings, and the control of thin coatings is more or less automatic. Heavier coatings tend to spall during the cooling from firing temperatures.

Parts coated with ceramics will stand an amazingly large amount of rough handling, so that parts handling does not constitute a problem. For example, if realignment of parts is necessary after the application of ceramic coatings, the parts may be placed in jigs, rubber mallets can be used, alignment jacks and alignment torch operations may be applied, and the realigning performed without chipping, crazing, or other damage to the coating. The ceramic is not affected by thermal shock at any temperature between −75°F. and 1,700° F.

In many applications, the rapid deterioration of the austenitic grades of stainless steel conducting the products of leaded fuels is due to high rates of carbon absorption with resulting surface embrittlement and loss of corrosion resistance. Enameling prevents this carbon absorption and provides a major improvement in design of these structures. The ceramic coatings were persistently adherent to the test header surfaces even though changed in appearance and almost impossible to detect except by spectrographic analysis.

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Autopilot Flight Tests *on the Constellation*

R. L. THOREN* AND W. L. HOWLAND†

Lockheed Aircraft Corporation

Introduction

THE OBJECT OF THIS PAPER is to describe the results of a study conducted to improve the safety and operation of the autopilot and its installation in the Constellation airplane. The investigation and study were prompted by an accident at Bari, Italy, June 23, 1949. Tests and experience on the airplane have shown the importance of careful autopilot tests. In the past, autopilots have frequently been installed in airplanes with little or no consideration as to whether or not the safety of the airplane was jeopardized. As the airplanes become larger, faster, and more complex, it is logical to expect the need and importance for autopilots to increase.

Early in the test program on the Constellation Model 649 airplane, consideration was given to the magnitude of the control forces produced by the autopilot. As originally installed, the autopilot was virtually impossible to overpower. Several methods for reducing servo torques were tested. Finally, resistors were inserted in series with the variable phase of all servos. As a result of these tests, the autopilot control forces were limited to a value thought to be satisfactory. However, on June 23, 1949, a Constellation was involved in an accident in which, after many weeks of intense investigation, it was the unanimous opinion of all investigators that the most likely cause for the airplanes to suddenly depart from cruising altitude was some type of failure of the autopilot in combination with a great likelihood that the pilot in command at the time did not have his seat belt fastened. It was felt that, as a result of the investigation, the autopilot failure alone would probably not have resulted in serious consequences if the pilot had been belted in at the time. Subsequent flight tests have indicated that a strapped-in pilot can regain control of the airplane if the autopilot fails in such a manner as to cause an abrupt maneuver. It was clearly established in the investigation that the primary cause for the accident was the result of excessively high speed caused from an unusual maneuver. It was therefore concluded that the autopilot was the probable cause of an unusual maneuver that was executed prior to the crash.

A second incident that caused additional concern over the autopilot occurred on August 10, 1949. This incident occurred on a Constellation Model 649 airplane. With no previous warning, the airplane suddenly rolled to an angle of approximately 50° when the airplane was being flown by the autopilot. The pilot on duty at the time was strapped in and immediately took over controls and disconnected the autopilot. This incident was directly and undeniably a result of autopilot failure, and it was as a result of this incident and the previous crash that an extensive and elaborate flight-test program was carried out by the Lockheed Engineering Flight Test Division.

An autopilot incident that occurred after the program described in this paper was completed, occurred on another Constellation on January 26, 1951. This incident could have been serious prior to conducting this program, as will be seen. On a flight in scheduled service with the autopilot in use, approximately 4 or 5 hours out, while flying at 19,000 ft. at cruise power, the elevator suddenly put the aircraft in a dive with a steep nose-down attitude. The Captain's safety belt was fastened, and he immediately disengaged the autopilot by pressing the wheel disconnect button. The ship was then flown uneventfully to its destination. Investigation upon arrival at destination revealed an open servomotor circuit (elevator channel) caused by corrosion of the wires. This incident is cited to substantiate the philosophy that a new autopilot installation must be tested for the effect on various types of malfunctions.

There are several expressions that will be used throughout this paper which require defining. The expression "stall force" is used to describe that force that is necessary to restrain the surface from moving when the autopilot is applying full servo force, or it is the equivalent of the pilot stick force that the autopilot can produce by its servo or power units. The "overpower force" is the force required of the human pilot to not only stop a runaway action of the autopilot, but to restore the control to its original position. The stall force and overpower force are different by a large factor in most autopilot installations, since, in overpowering a control surface while on autopilot, it is necessary to

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* Chief Flight Test Engineer.

† Flight Service Engineering Supervisor.

drive a gear train on the servomotor backwards. In addition, it is necessary to overcome the friction in the control system. The word "servo" or "servomotor" is used to describe the unit that supplies power or torque to the control system. A "servosystem" may be defined as a combination of units for the production of motion in which a source of power is controlled by the difference between an input signal and a specified function of the output motion in such a way that the output time is to be a desired function of the input or a specified predetermined relation of input signal variation with time.

The automatic pilot is a system of automatic controls which holds the aircraft on any selected heading, bringing it back without an overswing or hunting when momentary displacements occur, and simultaneously keeps the ship stabilized in pitch and bank. While under automatic control, the aircraft can be made to climb, dive, and execute coordinated turns. The autopilot installed in the Constellation Model 649 is an electric autopilot that has electric servomotors that are controlled by an amplifier; it, in turn, is controlled by signals from pickups that are stabilized by gyros. This autopilot is essentially one that is known as a displacement autopilot—that is, the signals to the surface put out by the amplifier are a function of angular displacement from a reference plane, and, for small deflections, the signal is proportional to this displacement. Some autopilots are known as rate autopilots. These are different from displacement type autopilots, in that the signals to the surfaces are created by the rate of displacement—i.e., velocity about each axis rather than a displacement. Numerous aspects of autopilots, their function, and behavior are not included in this paper.

The Lockheed philosophy on autopilot installations is that even if there are two different methods of disconnecting the servo or power units, in order to provide a safe configuration, the units should not be capable of putting out more torque—that is, force on the controls—than can be overpowered by the human pilot. This was the original idea on the first Constellation autopilot tests. The reason for this idea or philosophy is that no matter how carefully a system is designed, if the end unit in the system is capable of producing a large force, it is conceivable that a failure elsewhere in the system can cause the power unit to put out its maximum capacity. This means that the maximum force of the servo unit must be limited to a force on the controls which can be overpowered by the human pilot. The general reasoning behind the objection to the large forces is that it seems unnecessary, if not dangerous, for the autopilot to be able to develop forces larger than those a pilot can exert, since, if the pilot can satisfactorily control the airplane under all conditions, why should the autopilot be able to produce larger forces? In addition, if the autopilot should put a hardover signal on the controls, particularly the elevator and aileron, the pilot might not be able to shift his hands so that he could actuate the release button. (A hardover signal is a signal to the servo unit which causes a maximum force.) Furthermore, it can be reasoned that, under cruise condition where the pilot and copilot are relaxed and are not concentrating on flying or are not alert, the question of whether the pilot or copilot could disconnect the autopilot before the airplane attained a hazardous attitude or was subjected to high loads was raised as a result of the previously mentioned incidents. As a result of the elaborate tests and investigations carried on subsequent to the previously mentioned incidents, it was found that the original design philosophy was certainly correct but was not extended far enough. The additional study and investigation indicated that, in addition to limiting the overpower forces and the stall forces, a limitation on the "allowable time element" and maximum maneuvering load factor must be established. During the original autopilot tests, no consideration was given to the allowable time that the pilot should have between the time a malfunction occurred and before recovery must begin, so that during the recovery the airplane did not exceed placard air speed and/or limit load factor. If an autopilot has been in operation by a pilot for a considerable period of time with no malfunction, it must be reasoned that the pilot will not constantly be on the alert. Therefore, when an autopilot malfunction does occur, it is not logical to assume that the pilot will immediately take over the controls but, rather, that there will be some time interval between the time the malfunction occurs and when the pilot realizes that a failure has occurred and takes over controls. It is now believed, as a result of the investigation described in this paper, that at least 5 sec. should be allowed for the pilot to start recovery after a malfunction has occurred. Present tests are based on this amount of time. Regarding the second factor of maximum maneuvering load factor, it is now believed that the autopilot should not be capable of causing the airplane with any permissible loading—i.e., c.g. position and gross weight—to go below an acceleration of zero g's or above an acceleration of 2 g's. This, of course, applies only to commercial transport airplanes. There are two reasons for this: One is the possibly injury to passengers caused by their being thrown out of their seats or by objects falling on them. Second, and more important from a safety standpoint, is the difficulty a crew member might have in getting to the controls in the event of being out of station or of having a loose or unfastened seat belt.

Discussion of Types of Failures

In a joint conference between the autopilot manufacturers and Lockheed personnel, a complete detail analysis was made of all types of failures that could occur in the autopilot which would produce airplane maneuvers. Table 1 lists the types of malfunctions that can occur and their characteristics. As shown in the table, the type of failure could be caused by an open wire, a grounded wire, a shorting of two wires, or component failures such as tube failure, magamps, transformers, etc. In the table, the characteristic is given, as well as

TABLE 1

Classification of Autopilot Malfunctions

Type of Failure	Characteristics	Remarks
I. Loss of excitation on servo autosyn	Full torque signal followed by oscillation of the airplane. This could happen to one or all three surfaces simultaneously.	This has been tested with the new low forces and for one or multiple surface oscillation; the maneuver is mild and is not divergent. The pilot has an unlimited amount of time to correct conditions.
II. Follow-up signal circuit failure (a) Open circuit (b) Grounding of circuit	Full torque signal followed by oscillation	The new servo forces have been tested about all three axes and the resultant maneuver is a mild one. The pilot has an unlimited amount of time to correct the condition.
III. Tube failures (a) 6×5 tube	Possible hardover signal on one or more surfaces. Hardover signal persists regardless of plane attitude.	Relay and B^+ bias can protect against 6×5 failure and shorts in the B^+ supply. The other fix is a replacement of the 6×5 tube with the TE3, which is an improved tube. In addition, the low servo forces permit at least a 5-sec. "allowable time interval."
(b) 6 v 6 shorts	Short control grid to plate creates hardover signal.	Low servo forces permit adequate time and easily overpowered forces.
	Short screen grid to control grid creates hardover signal.	Same as above.
IV. Fluxgate malfunction	With the old configuration, a hardover signal to the rudder resulted.	With the course signal supplied to the aileron, a fluxgate malfunction can cause a maximum bank of 30°. This has been tested, and a stabilized bank condition will result. The pilot can easily overpower the rudder and aileron with the new forces.
V. Complex short circuits (a) Excitation to signal	Hardover signal on the affected surface	Low servo forces allow adequate time to overpower.

remarks covering the seriousness of the failure and possible fix.

After careful investigation and study, it was found that it was almost impossible to modify the autopilot so that it was incapable of producing hardover signals. It would require a completely redesigned unit to come even close to eliminating all types of malfunctions that could produce hardover signals. This careful investigation did, however, reveal that numerous fixes could reduce the possibility of hardover signals, but there were still such items as tubes burning out or shorting or opening of certain leads which would result in hardovers.

Discussion of Stall and Overpower Forces

Since malfunctions or failures cannot be eliminated from the autopilot circuitry, the most important factor governing the effects of the malfunction when it does occur is the servo stall force. In other words, the worst thing a malfunction in the autopilot can do is produce an electrical signal that will result in the servo producing the maximum force that the servo is capable of producing.* From a structural standpoint, the important thing is obviously the stall force, since the stall force is the direct measure of the amount of hinge moment which the servo is capable of producing. It is this quantity that governs the maneuvering loads that would result from a full servo torque applied to any one of the channels.

The overpower forces are important because, if the autopilot malfunctions and the airplane assumes an unusual attitude, the pilot either would have to disconnect the autopilot by pushing the disconnect button or manually overpower the control to stop the maneuver and initiate a recovery. As pointed out in the introduction, the overpower forces can be much larger than the stall forces because of friction in the control system and in the servo gear train. Thus, from a structural damage standpoint, the stall forces are all-important, and the overpower forces are important from the standpoint of whether the pilot can regain control easily or not. As a matter of fact, it is possible to have an installation where the pilot cannot overpower the autopilot at all.

References 1, 2, and 4 show the human capacity for exerting control forces under unfavorable conditions, such as the seat being adjusted too far forward or too far aft. It must be realized that, while the airplane is flying on autopilot, it cannot be assumed that the pilot will have his seat adjusted for optimum conditions from a control force standpoint. Therefore, the design conditions must be based on unfavorable conditions. These references show that reasonable overpower forces from a pilot's capability standpoint are as follows: elevator pull, 105 lbs.; elevator push, 80 lbs.; aileron, 40 lbs.; tangential wheel force and rudder, 180 lbs. These forces are in fair agreement with the original forces that the Lockheed Flight Test Division arbitrarily set up and met in the original autopilot configuration in the Constellation. The new forces arrived at are given and discussed later.

Effect of Power Boost System on Autopilot Characteristics

It is evident that there is a misconception that an autopilot works differently when used in combination with a power boost system, such as is used on all controls of a Constellation, than it does without power boost. This is entirely in error, because the power boost system ac-

* This statement does not include fire or smoke that might be worse.

tually does the same job that is done by other aerodynamic means such as leading-edge balance, spring tabs, etc.

The Constellation power boost system applies to the control surface a percentage of the effort that the pilot exerts on the controls. The power boost can exert no more than this percentage and, hence, operationally, is the same as aerodynamic balance, which could be termed aerodynamic boost. The boost ratio can be considered synonymous with aerodynamic balance ratio.

The autopilot is installed in the Constellation between the pilot's controls and the boost mechanism and, hence, applies the same types of forces that the human pilot would normally apply. The control forces on the Constellation are similar to the control forces required to produce a given maneuver on other transports of comparable size and speed. If a certain stick force is required to produce a given maneuver, such as to pull an acceleration of 2 g's, this force is the same for a power boosted airplane as it is for an aerodynamically boosted airplane, and the autopilot forces are the same. The behavior of the two types of airplanes would be identical as far as autopilot operation and pilot control forces are concerned. *The same force is required to overpower the autopilot servo with boost controls as with aerodynamically balanced controls.*

Structural Aspects and Load Limitations

During the test program leading up to the C.A.A. demonstration flight, an item of major concern was the structural loads to which the autopilot could subject the airplane in case of a malfunction. In this respect, there are three items to be considered: the load created by a sustained or steady acceleration, the maneuvering load caused by sudden movement of the surface, and the dynamic load under oscillating conditions. Preliminary tests had created some concern about the magnitude of the horizontal stabilizer loads during the oscillating condition created when the follow-up circuit was open. Because of this, the airplane was instrumented for measuring stabilizer load, e.g., acceleration, and fin load during the maneuvers created by an autopilot malfunction.

For the straight pull-up condition or pushover condition it was decided that the acceleration limits should be 2.0 and 0.0, the loads created by a steady acceleration were automatically taken care of since the airplane has a limit positive load factor equal to +2.5 and a limit negative load factor equal to −1.12. The next factor—that is, maneuvering loads—can be imposed on the tail due to rapid motion of the elevator. The maximum rate at which the various surfaces can be moved by the autopilot are governed by the maximum no-load servo speed. This speed, in the case of the PB-10 autopilot servomotor, is 4 r.p.m. This speed results in a maximum no-load elevator deflection rate of 9.45° per sec. Based on tail-load measurement made with an oscillograph on the Constellation airplane, it has been determined that an elevator rate of deflection can be as high as 40° per sec. without exceeding limit maneuvering tail load of the airplane, provided the maneuver starts from a balanced 1 g flight condition and within the placard speed range. Thus, the maneuvering tail load that the elevator servomotor can create is small, since the maximum rate of surface deflection is less than one-fourth the limiting rate of 40° per sec.

Oscillatory horizontal tail loads created by opening the follow-up circuit in the autopilot are equally noncritical based on oscillograph measurements. With an elevator servo stall force of 30 lbs. (equivalent wheel force), the maximum oscillating load recorded on the stabilizer was only 40 per cent of limit load. This occurred at 180 IAS with the elevator angle going from +4.2° to −3.2° and the airplane having a period in pitch of 3.9 sec. The oscillating loads at higher speeds were less critical, and the period became shorter. Incidentally, the maximum angular surface speed measured on the oscillograph for any of the oscillating tests was 7.6° per sec., which is reasonable when compared with the maximum no-load rate given above.

In numerous structural tests and measurements made in flight at Lockheed, the measurements have seldom shown that any portion of the wing or the nacelle structure becomes critical under even the most violent application of aileron. Lockheed was concerned with this problem years ago when it first incorporated power boost on the P38 aileron. Incorporation of the boost system in the ailerons of the P38 enabled the pilot to produce a much larger aileron deflection at a greater rate, particularly at high speed. A careful study was made of the loads imposed on the airplane as a result of this modification.[5] As a result of this study and numerous measurements made on other airplanes, it can be stated, in general, that it is difficult to move the ailerons fast enough to create critical wing loads. On the Constellation airplane, maximum roll tests have been made at both 160 IAS and 250 IAS without exceeding limit loads. At 250 IAS, the maximum aileron angles obtained during these tests were 6° up and 5° down. The control force applied was a 38-lb. couple, and the maximum rate of surface deflection was 12° per sec. At 160 IAS, the maximum surface angles were 21° up and 10° down, for about the same control force with the surface rate of deflection as high as 25° per sec. These aileron deflections and rates are far in excess of those that the autopilot is capable of producing both as to force and surface deflection rate. The autopilot's maximum no-load aileron angular deflection rate is 4.69° per sec. Measurements show that, with a hardover aileron signal on the autopilot at both 220 and 260 IAS, it takes the airplane approximately 5 sec. to roll to a 30° bank angle. The resultant wing stresses caused by hardover signal on the aileron are low when compared with the design limits.

The allowable rudder angle and forces are governed principally by the fin loads resulting from a quick release of the rudder. This condition can easily occur under autopilot operation by having the pilot push the autopilot disconnect switch after a malfunction has created a hardover signal on the rudder channel. Under these conditions, the pilot unintentionally causes a quick release of a rudder hinge moment. Structural measurements on the airplane show that if a rudder load is suddenly released at a speed of 271 IAS from a stabilized yaw of 6.8°, the fin load will reach limit. At 200 IAS, this yaw angle is 14°. With the present autopilot configuration, a hardover rudder signal results in a maximum yaw of 3° at 260 IAS. This is less than half the permissible angle. Tests run at 200 IAS resulted in a maximum yaw angle of only 6°. Here again, the yaw angle is less than half allowable. In regard to the maximum maneuvering loads caused by rudder motion, the no-load rudder angular deflection rate possible with the servo is 10° per sec. Since the vertical tail can become critical under fishtail maneuver, the fin loads were measured under oscillating conditions caused by the autopilot. Under these conditions, the strain gage measurement showed that the fin loads never exceeded 35 per cent of limit load.

Discussion of Flight-Test Program

The flight-test program was directed toward determining the following:

(1) The margin of safety between the structural loads imposed by malfunction of the autopilot and the structural limitations of the airplane.

(2) The maneuvering accelerations resulting from malfunction.

(3) The necessary corrective action for different types of failures.

(4) The altitude lost during the maneuver resulting from malfunction.

(5) The time interval available before the pilot must apply corrective action.

In order to determine the quantities listed above, several pieces of test equipment were installed in the airplane. One item was an electrical test panel that could create a large number of autopilot circuit changes in flight. This panel, located in the navigator's compartment directly behind the cockpit, incorporated switches that could remove follow-up excitation from one or all channels, permit reversal of fluxgate signal, short or open various circuits or components, and simulate tube failures. All types of malfunctions could be artificially created by this panel. Also mounted in this panel was a signal generator that consisted of an autosyn, and, by properly selecting a switch, a hardover signal could be produced on any of the three axes which would not decrease with the ship's attitude or surface position. Back in the cabin was mounted a table on which the various autopilot monitors were located.

The instrumentation for these tests consisted of an automatic photographic recorder and an oscillograph. The automatic photographic recorder was used to record the following quantities: time, indicated air speed, altitude, acceleration, pitch, and roll angle. This re-

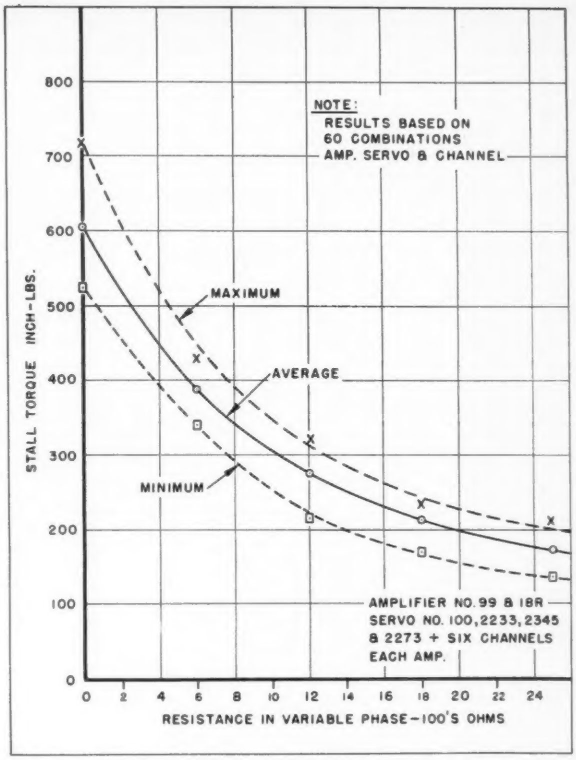

Fig. 1. Pioneer PB-10 servomotor stall torque variations vs. resistance in variable phase.

corder consisted of a 35 mm. camera and was capable of taking pictures at time intervals ranging from 0.05 sec. to 30 sec. It was used for obtaining time histories of the various maneuvers resulting from malfunctions. The oscillograph was used for recording quantities particularly of importance from a structural standpoint. It was primarily installed to obtain tail-load measurements during oscillating conditions. The following quantities were recorded on the oscillograph: elevator control force, elevator position, rudder control force, rudder position, aileron control force, aileron position, horizontal stabilizer bending, vertical stabilizer bending, c.g. acceleration, rate of roll, rate of pitch, rate of yaw, elevator servo current, aileron servo current, and rudder servo current. From the records obtained on the oscillograph, the magnitude of the dynamic loads on both the horizontal and vertical stabilizer could be ascertained. From the record of control forces, the magnitude of the stall and overpower forces could be determined. The last instrumentation item was the yawmeter, which consisted of a boom approximately 8 ft. long mounted near the left wing tip. A sensing unit was mounted in the end of the boom with a vane attached and an indicator in the cockpit instrument panel. This instrument was used for measuring the yaw angle

Table 2

Control Surface	Stall, Lbs.	Overpower, Lbs.
Elevator	50	82
Aileron	40	60
Rudder	140	180

during various sideslip conditions and rudder hardover signals.

As a result of the original autopilot installation tests on the Constellation, the stall and overpower forces were arrived at, as shown in Table 2. The forces are the average obtained from 13 production airplanes. The original values on which this average is based were selected on the basis of the pilot being able to overpower them, as was discussed earlier. The easiest way to decrease the effective control force produced by the PB10 autopilot servo is to add resistance to the variable phase of the servomotor. The addition of resistance will not only lower the stall force but also lower the overpower forces. In order to arrive at the necessary resistance to reduce the control forces to an acceptable amount, each of the control systems on the ship was calibrated for control force vs. resistance. To obtain a good average figure for production airplanes as well as a maximum and a minimum, 60 different combinations of magnetic amplifier and servos were tested. Results of these tests are shown in Fig. 1. The upper line in this figure gives the maximum stall torque, and the lower curve gives the minimum stall torque. Based on this curve, the following resistance was added to each of the control channels in production airplanes:

Elevator servo channel	1,650 ohms
Aileron servo channel	1,200 ohms
Rudder servo channel	600 ohms

These resistors resulted in new forces that, under malfunction conditions, could produce forces shown in Table 3.

TABLE 3

Control Surface	Stall, Lbs.	Overpower, Lbs.
Elevator	$30\,^{+0}_{-10}$	50 ± 10
Aileron	$30\,^{+0}_{-10}$	50 ± 10
Rudder	$120\,^{+0}_{-60}$	180 ± 30

These forces, in addition to being easily stalled and within the human capacities for overpowering under unfavorable seat conditions, effect the airplane as shown in Fig. 2. This figure shows a rather complete summary of the result of the autopilot malfunction vs. initial air speed for the stall forces given in Table 3.

On the right-hand side of this figure is shown the maximum and minimum acceleration resulting from a full elevator servo torque applying itself to the controls for 5 sec. uncontrolled. It should be noted that the maximum acceleration for all speeds was 2 g's, and the minimum was +0.2 g's. These curves show the maximum and minimum acceleration resulting from both the maneuver and the recovery from the maneuver. The reason the maximum acceleration on recovery is 2 g's is because that was the figure decided upon before running the test, and the pilot pulled up to this acceleration during recovery. This fact is important, since it influences the maximum air speed resulting during the recovery. Accelerations are well within the airplane's capabilities mentioned before—namely, +2.5 and −1.12 load factors.

The maximum and minimum air speeds resulting from the full elevator servo torque are seen in the lower

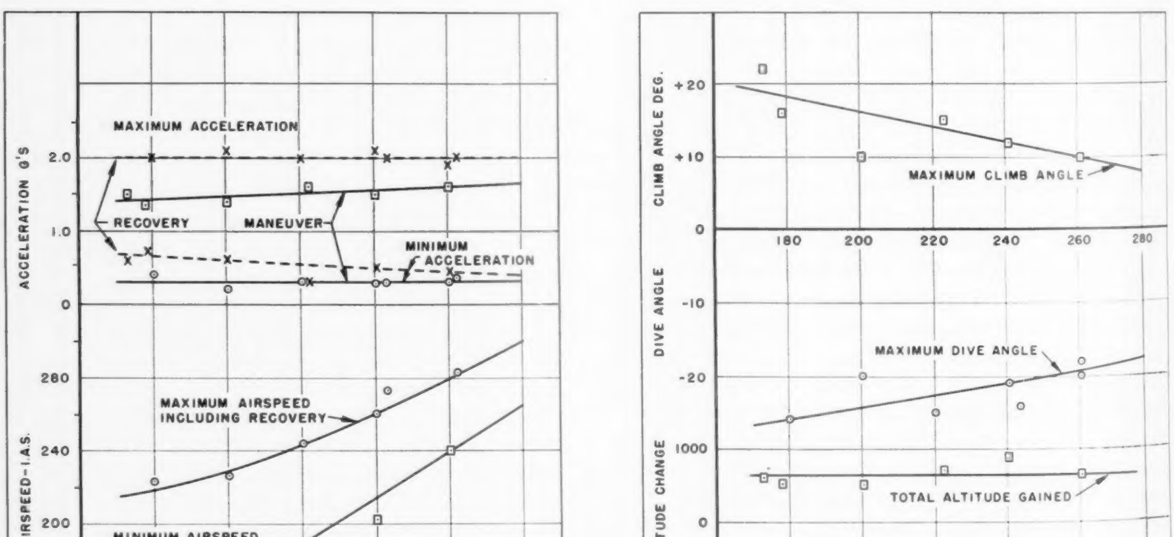

FIG. 2. Effects of autopilot malfunctions vs. initial air speed.

left-hand corner of Fig. 2. The maximum air speed is the result of a nose-down signal, and the figure given is the maximum air speed including recovery made at the 2 *g*'s, as mentioned previously. The minimum air speed is the result of a nose-up malfunction, and, during the recovery from a nose-up malfunction, the recovery acceleration in all cases was held to less than that caused by the autopilot servo. The maximum level flight speed for the airplane is 271 IAS and the never-exceed speed is 324 IAS. This figure shows that, if a nose-down malfunction occurs at the maximum level flight speed of 271 IAS, a large margin exists between the maximum air speed resulting and the 324 IAS. The upper curve on the right-hand side of Fig. 2 shows the maximum climb angle resulting from a full servo torque uncontrolled for 5 sec. The curve below this one shows the maximum dive angle resulting from a nose-down signal. The maximum dive angle can be an important quantity, since it is serious to get a large airplane into a dive angle greater than 30° because of the care that must be exercised in recovering. Finally, the bottom curve on the right-hand side shows the total altitude loss or gain during the entire maneuver, including recovery. It should be noted that tests were made up to very nearly the maximum level flight speed of 271 m.p.h. IAS, and the maximum air speed remained well below the placard speed of the airplane.

Monitor Tests

During this flight-test program, four different types of monitors were tested: The first type was a vertical acceleration switch that could cut off the autopilot at a preset value of positive or negative acceleration. This monitor was found to be unnecessary with the new low forces arrived at, since, under maximum torque autopilot malfunction, the airplane will not exceed safe and reasonable acceleration for any speed or c.g. location. Furthermore, for the acceleration limiter to give attitude protection (i.e., climb or dive angle), the setting would be so low as to be a nuisance. The actual tests on this unit showed that it worked well; however, several nuisance trips were encountered when flying through moderately rough air. The unit tested was just a simple acceleration switch. However, it would be possible to design a unit with a rate of change of acceleration incorporated which would perform the function of being an anticipator and would help eliminate overshooting a desired *g* limit.

The second type of monitor tested was one called a servo signal time detector. This device consisted of a sensing circuit that would trigger a relay and disconnect the autopilot if the servo current exceeded a certain amount for a predetermined time. This type of monitor will definitely not protect for gentle malfunction conditions. It will only operate satisfactorily when nearly a full torque signal is being applied to the servomotor. The flight tests made indicated that this type of monitor works well on hardover signals only. It was also obvious from the test that it required more development before it would be suitable for any production installation.

The third type of monitor tested was called a reverse signal detector. This device turns the autopilot off if the autopilot, due to a malfunction, called for a surface motion that was incorrect. That is, if the nose of the airplane was moving up and the autopilot called for elevator motion to cause more up-signal, the reverse signal detector would cut the autopilot off. This is fundamentally a good type of monitor. It will operate and was tested for hardover signal conditions; however, it was not tested for mild malfunction conditions, but there is no reason why it would not work satisfactorily. Its chief objection is that it is an extremely complicated system and also has a serious objection of being costly and heavy. It practically consists of a second autopilot. The tests also indicate that it needs considerably more development in order to handle such conditions as controller operation, and the tests further indicated that it would probably need some type of a time delay circuit in order to handle certain controller operations.

The last type of monitor tested was the type called an airplane attitude limiter. This device consists of a vertical gyro with contacts that can be preset at various angles of bank, climb, and dive. This monitor appeared to be the one most suitable for protecting against a gradual deviation in attitude of airplane whether it be in pitch or roll. This type of monitor is definitely sufficient in itself for an autopilot installation where there are small forces. This is because it is impossible for the autopilot to cause high airplane accelerations. This type of monitor definitely protects against slow deviations such as slow rolls. It definitely protects against the airplane attaining steep dives or climb angles with either gradual or hardover signals. It is believed that with some development an attitude limiter can be made to be a "fail-safe" device. Providing a "fail-safe" design is a serious problem with all types of monitors. An additional advantage of the attitude limiter is that it is believed it can be made reasonably free from nuisance trips.

Another type of monitor which was considered for testing but was eliminated as a result of analysis is the control-surface travel-limiting monitor. Analysis of the airplane shows that limit positive acceleration can be imposed on the airplane with the elevator up to 0.5° and limit negative acceleration can be produced with a down elevator angle of only 4.2° at the proper gross weight and c.g. position. In contrast to these small angles, during approach condition with forward c.g., as much as 16° up elevator is required to balance the airplane. Thus, it is obvious that one cannot protect the airplane at both high and low speeds and various c.g. positions by preset elevator travel limits.

It appears from these tests that, if it were necessary to make an autopilot installation with large forces in order to fly the airplane satisfactorily under all conditions, monitors would be required to provide a safe installation. At the present time, it is felt that monitors are not sufficiently developed to go into air-line airplanes, and, as long as there are low forces, they are definitely not considered mandatory. It is obviously possible to make a monitor that is a combination of several of the above types. If an autopilot is capable of producing large forces and applying them suddenly, the monitor will probably have to be complicated to adequately protect the airplane.

Conclusions

The flight tests described in this paper show beyond any doubt that the servo forces arrived at can be termed as "absolutely" safe, provided the pilot or copilot does not allow the airplane to go uncontrolled, after a malfunction occurs, for longer than 5 sec. The flight tests show the effects of autopilot malfunction, and the tests show that the maximum maneuvering acceleration that the autopilot could produce, with the airplane loaded at the aft c.g. limit, did not exceed 1.65 g's or 0.2 g's. These tests show that the only quantity that becomes at all critical for malfunction is the maximum air speed. If, for example, the malfunction should occur at a maximum level flight speed of 271 m.p.h. IAS, the pilot has 5 sec. in which to start recovery. With an acceleration of only 2 g's, the airplane does not exceed 300 m.p.h., which leaves a large margin below the never-exceed placard speed of 324 m.p.h. Summarizing, it could be stated that the autopilot forces, in addition to being easy to stall and within the human capacities for overpowering under unfavorable seat conditions, meet the following requirements:

(1) The servos cannot produce an airplane acceleration greater than 2 g's at any airplane approved loading or speed.

(2) The servos cannot produce an airplane acceleration less than 0.0 g's at any airplane approved loading or speed.

(3) With full servo torque, it will allow the pilot at least 5 sec. before recovery action must start.

(4) Placard speed or 2 g's need not be exceeded after a full servo torque signal has been applied uncontrolled for 5 sec. at any speed or approved airplane loading.

(5) Stresses in any part of the airplane due to oscillating signal conditions will not exceed 50 per cent of design limit.

(6) Maneuvering loads resulting from maximum surface speeds are less than 50 per cent of design limit.

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Analysis of Systems for Automatic Control of Aircraft

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Summary

The paper points out the rapid growth in a new era of automatic control based primarily on the addition of mechanized brains to automatically controlled processes. It also demonstrates this growth with examples, especially for automatic control of airplanes and guided missiles.

The fundamental objectives of a dynamic analysis of an automatic control system are then discussed. This is followed by a summary of the basic elements that are common to automatic control systems. The paper emphasizes the necessity of the *systems approach* in automatic control analysis and the usefulness of the "pyramiding" process in this approach.

The "pyramiding" process is demonstrated for a system for automatic control of aircraft, starting with the aircraft body modes (which are the primary objects of control) and expanding progressively to include the dynamics of the medium, the multielastic structure, the aerodynamic controls, the power boost, the autopilot, the computer, the seeker, and the target.

A summary of the more important analytical, numerical, and machine methods of dynamic analysis is then presented, covering the general approach of each method and indicating its advantages and disadvantages.

The effectiveness evaluation of systems for automatic control of weapons is briefly discussed in terms of system accuracy, system reliability, weapon lethality, and target vulnerability.

It is concluded that the most practical approach to analyzing complicated automatic control systems is the use of mechanical simulators and computing devices. Recommendations for expansion and improvement of mechanical simulation and computation facilities are made, as well as recommendations for intensive study of nonlinear dynamics, lateral dynamic stability of aeroelastic aircraft, coupling between conventional aircraft flutter modes and servo equipment, and aerodynamic configurations for optimum automatic control systems.

This paper covers a systematic application and extension of the fundamental concepts discussed in a paper presented by the author at the I.A.S. Annual Summer Meeting in Los Angeles, July 13, 1950.

List of Symbols
(For aircraft only)

U_0	= aircraft forward velocity, steady flight
u	= change in aircraft forward velocity
W, w	= aircraft normal velocity (along z axis)
θ	= aircraft pitch angle
D	= operator d/dt
$\dot{\theta}$	= $\dot{\theta} = D\theta$ (also, $\ddot{\theta} = D^2\theta$, $\dot{w} = Dw$)
n_0	= aircraft center of gravity acceleration along negative z axis
n_i	= command (input) acceleration
X	= force acting on aircraft along x axis
Z	= force acting on aircraft along z axis (normal force)
M	= moment acting about aircraft y axis (pitching moment)
x, y, z	= aircraft stability ("body") axes for zero steady-flight normal velocity W_0
X_u, Z_w, etc.	= Aircraft stability derivatives: X_u = partial of X with respect to u, Z_w = partial of Z with respect to w, etc.
M_{EH}	= elevator hinge moment
M_{ETH}	= elevator control tab hinge moment
V_g	= vertical gust velocity
α_g	= $\alpha_g \cong V_g/U_0$
P	= generalized force
d	= generalized deflection
δ	= control surface deflection (δ_e, elevator deflection; δ_{et}, elevator control tab deflection)
m	= aircraft mass
I	= aircraft moment of inertia about y axis (pitching moment of inertia)
F	= transfer function
$c.g.$	= aircraft center of gravity
l	= distance from c.g. along x axis
ω	= circular frequency
i or j	= imaginary unit ($i = j = \sqrt{-1}$)

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(I) Introduction

Recent history has shown that the field of automatic control has been expanding at an ever-increasing pace, especially since the end of the last war, and especially in the field of automatic control of aircraft. In fact, many people feel that we are rapidly embarking on a new industrial era based on the addition of mechanized brains to automatically controlled processes. In the past, automatic control systems have been primarily *servo* systems, with little computation involved; however, today the emphasis is on the development of computing elements that add *intelligence* to the system. This applies not only to the control of aircraft and weapons, but also to industrial processes. The change to the new industrial era is, of course, accompanied by the old but serious sociological problems arising from the replacement of man by the machine.

One of the most important parts of this expansion has been in the development of automatic control systems for guided missiles. We can give the missiles speed; we can make them strong enough, but our biggest problem is still with guidance, especially automatic guidance.

In addition, the development of automatic systems for piloted military aircraft has recently received great impetus. In fact, the fully automatic interceptor, which uses the pilot merely as a monitor of the operation, should soon become a reality.

Commercial air-line systems for complete automatic control, including automatic take-off, climb, cruise, descent, and landing, should also be a practical reality in a few years.

To further demonstrate this rapid growth, a few specific examples of systems for automatic control will be presented.

Basic systems for automatic control of piloted aircraft, considering them in the order of operational sequence, are:

(1) Automatic ground controlled interceptor systems that vector the interceptor from the ground to the close-range target area
(2) Automatic navigation and cruise control systems (for long-range en route guidance)
 (a) Radio sensing systems
 (b) Magnetic sensing systems
 (c) Celestial sensing systems
 (d) Inertial sensing systems, etc.
(3) Automatic tracking and fire-control systems
 (a) Movable-gun and fixed-gun systems
 (b) Disturbed sight and director systems
 (c) Transient firing ("snap shooting") systems
 (d) Automatic bombing systems, etc.
(4) Automatic return-to-base guidance systems
(5) Automatic landing systems
 (a) Automatic instrument landing systems
 (b) Automatic ground controlled approach systems, etc.

When examples of systems for automatic control of missiles are considered, there are found surface-to-surface, surface-to-air, air-to-air, and air-to-surface systems, as well as beam-rider, command, seeker types, etc., and the many permutations and combinations of these basic types.

Additional examples of aircraft dynamic systems which have been analyzed by automatic control techniques are[1] aeroelastic (flutter) systems, gust-load alleviation systems, aerodynamic servo (control tab) systems, etc. In these cases the aircraft itself is treated as a servomechanism with aeroelastic feedbacks (including the dynamics of the elastic structure and the aerodynamic medium). Other applications of automatic control techniques to aircraft systems are the stabilization and control of fuel flow in jet and rocket power plants, the stabilization and control of turbo-propeller systems, etc. The control of underwater torpedoes, which are a type of missile, is another practical application.

It is worthy of note that the analysis techniques used in automatic control can be applied to many other fields. A particular field in which these techniques are applicable, but where little basic work has been done, is the field of dynamic stress analysis (i.e., dynamic elasticity within a structure). Another application is the stabilization of fire-control systems in military tanks, etc. However, perhaps the greatest potential application of automatic control philosophy and servomechanism engineering techniques is in the field of industrial processes. For example, these techniques could be applied to the many manufacturing processes in the aircraft industry, to the cracking process in the oil industry, to the control of marine and stationary power plants, to the control of the processes for manufacturing nitrates, to the brewing process, the printing process, etc. Although some of these processes are already semiautomatic, mechanized brains have yet to be added to the control systems.

These are only a few of the many examples that indicate the rapid growth in the new era of automatic control.

In the dynamic analysis of any of these automatic control systems there are certain fundamental objectives that should be considered.

(II) Objectives

The fundamental questions to be answered in a dynamic analysis of an automatic control system are:

(1) Is the system stable or not?
(2) If it is stable—
 (a) What is its degree of stability?
 (b) What is its response time?
 (c) What is its accuracy?
(3) What is its effectiveness in accomplishing its primary purpose?

Other basic questions concerning speed of response, overshoot, overloading, fail-safety, etc., are usually considered. The Nyquist[2] criteria, for example, can be used in a linear analysis to determine whether or not the system is stable.

If it is stable, quantitative measures of the degree of stability and the response time can be obtained from the transient response of the system to particular inputs. The degree of stability of a particular mode in the transient response is often measured in terms of the per cent of critical damping for that mode, whereas the response time of the system is often measured in terms of the time required for the net transient response to damp to, and stay within, a band between 95 and 105 per cent of the steady-state response. The accuracy of a system may be defined in many ways. For example, the accuracy of a command guidance system may be defined by the ratio of the steady-state output acceleration to the steady-state input (command) acceleration. However, the accuracy of a guided missile system is usually defined in terms of the accumulated miss distance as determined from actual system performance or by trajectory analysis.

The effectiveness of a system for automatic control of a weapon is usually measured in terms of its probability of kill. This, in turn, depends on the system accuracy (i.e., the miss distance), the system reliability, the weapon lethality, and the target vulnerability.

These fundamental objectives are more easily accomplished with an understanding of the basic elements that are common to automatic control systems.

(III) Basic Elements

The basic elements that affect the dynamic response of a system for automatic control of aircraft are: (1) the system inputs, (2) the sensing elements, (3) the computing elements, (4) the actuating elements (servos), (5) the controlled elements (in this case, the aircraft and its propulsive subsystem), and (6) the operating medium (in this case, the air).

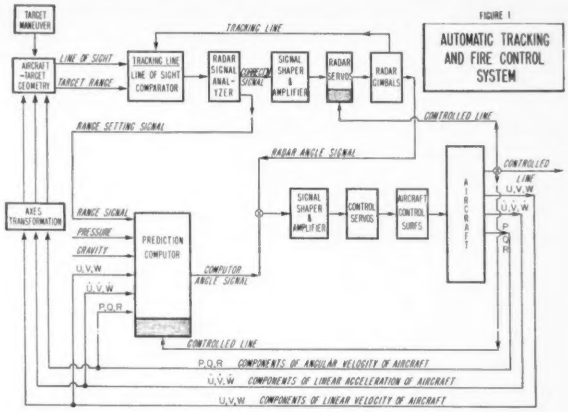
The inputs to a system may, for example, be a target motion, a beam reference, a terrestrial reference, a celestial reference, an inertial reference, or a combination of these. Noise, of course, is an unwanted input of major importance which enters throughout the entire control system.

The sensing elements "sense" the inputs to the system as well as the response of the system—i.e., there are *input* sensing elements and *feedback* sensing elements. Examples of input sensing elements are radar, optical, heat, radio beam, and sound sensing equipment; examples of feedback sensing elements are instruments such as control surface pick-offs, gyros, accelerometers, etc., as used in an autopilot. The functions of the sensing elements correspond directly to those in the human body, such as seeing, hearing, feeling, tasting, smelling, etc.

The computing elements act as the brain in the system. Here again, there are *input* computing elements and *feedback* computing elements. The director-type computer used in an automatic fire-control system is an example of an input computing element, whereas the disturbed-sight computer is an example of a feedback computing element. An electrical shaping circuit used in the feedback path of an autopilot (see Fig. 10) is another example of a feedback computing element. Computing elements, in general, have the task of smoothing the input data received from the sensing elements and providing intelligence in the system by establishing the proper proportions of displacement, derivative, and integral control for the best compromise between system stability and system controllability. It is the addition of these computing elements to the automatic control system which accounts for the rapid trend toward the new industrial era referred to at the beginning of this paper.

The actuating elements are the "muscles" of the system. They usually received their signals from the computing elements; however, in some simple systems that do not contain computing elements, they may receive their signals directly from the sensing elements. Typical examples of actuating elements are electric servos, hydraulic servos, pneumatic servos, aerodynamic servos (control tabs), etc. The actuating elements may, of course, have their own internal or external feedback loops, in which case they are usually referred to as servomechanisms. An automatic pilot is a good example of this.

The controlled element (in this case, the aircraft and its propulsive subsystem) is a complicated dynamic system in itself. For example, it includes the degrees of freedom of the aircraft as a whole (body modes), those of the aerodynamic and power-plant control systems (e.g., the elevator, rudder, aileron, and throttle control systems), and the elastic structural degrees of freedom



associated with bending and torsion of the wings, fuselage, and tail.

The degrees of freedom within the operating medium (the air) must be considered in cases where aeroelastic coupling is important. These degrees of freedom within the air itself are sometimes included with the dynamics of the elastic structure, thus reducing the number of basic elements in an automatic control system to five. However, in this fundamental breakdown, the author has chosen to consider them separately. Also, the dynamic characteristics of the medium itself are often described by the aerodynamic transfer function, of which the stability derivative is the special (zero-frequency) case.

Thus, it can be seen that systems for automatic control of aircraft relate the sciences of many different fields. It is not merely a problem of the marriage of aerodynamics and servos, as some authors have indicated; instead, it is a much more comprehensive dynamic problem. For example, Fig. 1 shows a typical system for automatic tracking and fire control of aircraft, involving target plus aircraft kinematics, radar dynamics, computer dynamics, autopilot dynamics, aerodynamics, structural elasticity, etc.

Many people have specialized in each one of these scientific fields, but comparatively few have specialized in the problem of putting the basic elements together to make a systems analysis of the whole. Because it is virtually impossible for any one man to know all of the details in a comprehensive system, it is advisable to accomplish a systems analysis through the combined efforts of a group of specialists who consider the system as a whole in addition to contributing in each of their special scientific fields. With regard to airplanes, this idea of systems analysis is certainly not new. The airplane manufacturer has always had the problem of integrating hydraulic, electrical, aerodynamic, structural, and other subsystems. The control system problem is much more critical for missiles, however, since no monitor is carried in the missile to override the control system if necessary.

A study of the dynamics of a complete system for automatic control of aircraft logically divides into

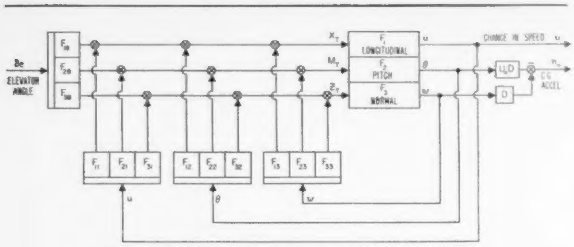


FIG. 2. Rigid aircraft (longitudinal case).

three phases. Phase One is the study of the *longitudinal* dynamics, Phase Two is the study of *lateral* dynamics, and Phase Three is the *three-dimensional* superposition of Phases One and Two, including coupling effects between the lateral and longitudinal cases. The examples covered in this paper apply primarily to the longitudinal phase.

All of the systems for automatic control of aircraft have at least one basic element in common—obviously, the *aircraft itself*—and, since the aircraft "body modes" are the primary objects of control, it would seem logical to start with these and develop the automatic control system around them by means of the "pyramiding" process.

(IV) PYRAMIDING PROCESS

(*A*) *Rigid Aircraft*

The longitudinal dynamics of the aircraft body modes can be represented by the well-known rigid body equations of motion. For small linearized motions these equations are as follows:

$$X_{\delta_e}\delta_e + X_u u + X_\theta \theta + X_w w = mDu$$
$$Z_{\delta_e}\delta_e + Z_u u + (Z_\theta + U_0 mD)\theta + Z_w w = mDw$$
$$M_{\delta_e}\delta_e + M_u u + M_\theta D\theta + (M_w + M_{\dot{w}}D)w = ID^2\theta$$

where D is the operator d/dt.

The block diagram corresponding to these equations is shown in Fig. 2. The input to the system is elevator motion, and the output is aircraft response, indicated in this case by change in speed and change in normal acceleration at the aircraft center of gravity. It should be pointed out that this block diagram is a generalization of these equations, because the stability derivatives in the equations are special cases of the aerodynamic transfer functions represented by F in the block diagram. Although some people choose to consider the aerodynamic transfer function merely as a complex stability derivative that is a function of frequency, the usual concept of the stability derivative is the zero-frequency value of the aerodynamic transfer function.

The process of pyramiding from the rigid body modes to include aeroelastic effects will now be demonstrated.

(*B*) *Aeroelastic Aircraft*

Experience has shown that, in many cases, the elastic properties of the air frame must be included in any comprehensive analysis of an automatic control system, especially since these effects on the autopilot sensing elements can be of considerable magnitude, also, because for large flexible aircraft they sometimes have an appreciable influence on the body motion itself, and because they often should be included in structural design criteria. The word "aeroelastic" as used in this paper includes the elastic deflections of the aircraft structure and the dynamics within the aerodynamic medium.

An expansion of the block diagram for the rigid aircraft (Fig. 2) to include the dynamics of the multi-elastic structure and the dynamics of the aerodynamic control system is shown in Fig. 3. This diagram represents the aircraft as a large servomechanism with aeroelastic feedbacks, inertia cross-couplings, etc. Provision for gust inputs has also been made. The principal of "pyramiding" from the basic body modes is demonstrated in this case, since the expansion of the rigid body case to the general aeroelastic case merely consists of the addition of more blocks, connections, and feedbacks. A more detailed explanation of the general block diagram of Fig. 3 is given in reference 1. It is also evident that the various simpler cases are obtained from the general case by setting a number of the blocks of Fig. 3 equal to a constant or zero.

The numerical work of obtaining the transfer functions for the individual blocks and for the overall system (shown in Fig. 3) has been completed by the Douglas Aircraft Company for the C-74 and C-124 airplanes, using the TFF method[1] of analysis. Typical transfer

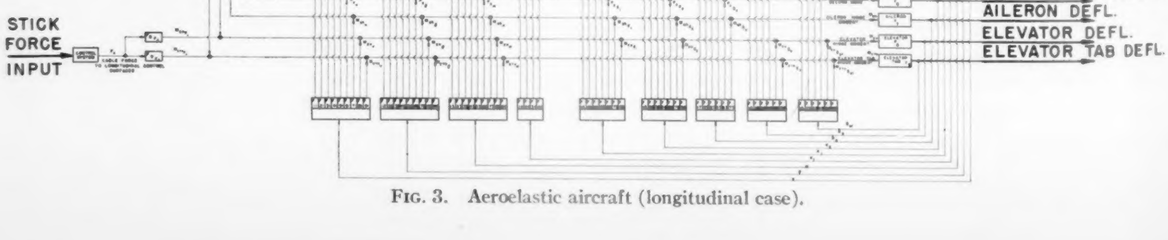


FIG. 3. Aeroelastic aircraft (longitudinal case).

function curves for the C-74, showing the good correspondence between this theoretical work and flight-test data, are shown in Figs. 4 and 5. From this, we conclude that the block diagram of Fig. 3 and the associated TFF method of analysis will permit adequate representation of the longitudinal dynamics of an aeroelastic-aircraft, at least from 0 to 5.5 cycles per sec. in the frequency spectrum.

Fig. 3 may also be expanded by further "pyramiding" to include in the automatic control system the dynamics of an aeroelastic gust load alleviator, as shown in Fig. 6. Details of this system are also discussed in reference 1.

Additional "pyramiding" to include power boosts, autopilots, computers, seekers, targets, etc., in this general block diagram is discussed in the following sections of this paper, which cover a systematic application and extension of the fundamental concepts discussed in reference 1.

(C) *Aeroelastic Aircraft Plus Power Boost System*

The Douglas Aircraft Company has made an analysis of a typical power boost (hydraulic servo) system, including certain nonlinear effects, such as hydraulic fluid compressibility, pressure drops across orifices, valve overlap, stiction, etc. Fig. 7 shows the block diagram representing this system. The input to the system is stick force, and the output is aircraft response. The actual system equations indicated by the diagram are not pertinent to this paper, and the diagram is included here merely to indicate the connection of the power boost system to the aircraft.

Fig. 8 shows in expanded detail the connection of the hydraulic servo system to the longitudinal system for the aeroelastic aircraft. In this block diagram, the longitudinal force balance and the effect of change in speed on the other parameters in the system have been neglected, and the block for fuselage bending and torsion, as shown in the general aeroelastic diagram of Fig. 3, has been somewhat amplified. Also, this diagram has been arranged in a manner that brings out clearly the correspondence between the block diagram and the matrix representation of a dynamic system. This figure demonstrates how a control system simulator can be built in components that can then be interconnected or "pyramided" to form the overall simulator system.

An autopilot could then be added to the aeroelastic aircraft plus power boost system, and it would only be a matter of definition as to whether the power boost system should be considered as part of the aircraft system or part of the autopilot system.

The case of adding an autopilot to an aeroelastic missile will now be considered.

(D) *Aeroelastic Aircraft Plus Autopilot*

Consider first a simplified block diagram for the longitudinal dynamics of an aeroelastic missile (without autopilot) as shown in Fig. 9. Elevator fin deflection is the input to the system and missile normal acceleration is the output. Elevator fin deflection creates aerodynamic forces that create body bending deflections, and they, in turn, feed back to affect the aerodynamic forces. The addition of a typical autopilot to this block diagram is shown in Fig. 10, with the effect of structural bending included in the aircraft plus autopilot "stability" loop.

Experience gained the hard way in actual missile flight tests has shown that the effects of structural bending on the feedback sensing elements in the autopilot can be extremely important. These effects are included by means of the transfer functions F_{35} and F_{36}. F_{35} provides for the acceleration effect of the body bending on the accelerometer, and F_{36} provides for the rotational effect of body bending on the pitch rate gyro.

Also included in Fig. 10 are the electrical shaping networks that add the "computation" (i.e., mechanized brains) in the input and feedback paths of the autopilot, as referred to previously in this paper.

Comparison of the block diagram for the longitudinal dynamics of the aeroelastic missile (Fig. 9) with the more general diagram of Fig. 3 shows that the former is a special case of the latter, obtained by setting several of the transfer functions in the general diagram equal to a constant or zero. It is evident therefore that the combination of aeroelastic missile plus autopilot, as well as combinations of aeroelastic missile plus autopilot plus computer plus seeker plus target, may be obtained from the general diagram of Fig. 3 simply by additional "pyramiding." This more complete combination will now be demonstrated.

(E) *Aircraft Plus Autopilot Plus Computer Plus Seeker Plus Target*

The addition of a computer, a radar seeker, and a target to the combination of aeroelastic missile plus

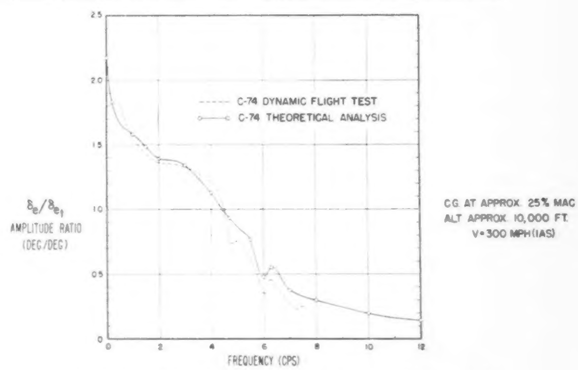


FIG. 4. Transfer function δ_e/δ_{et} amplitude ratio.

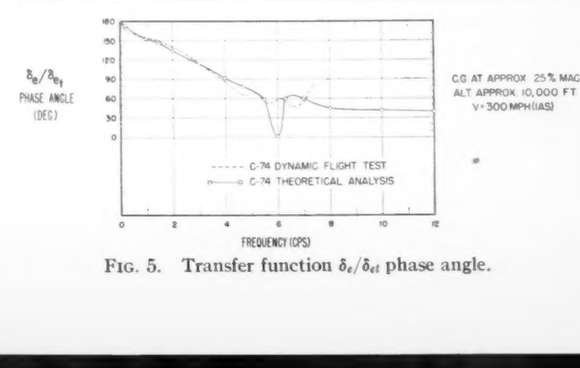


FIG. 5. Transfer function δ_e/δ_{et} phase angle.

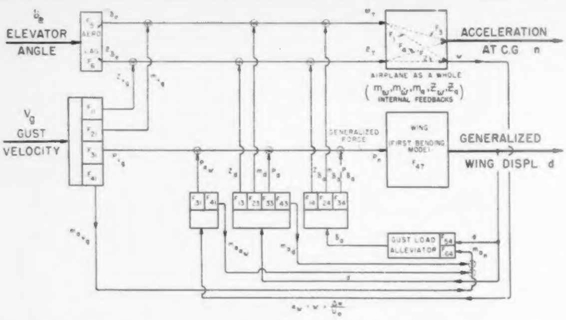


FIG. 6. Gust load alleviation system (longitudinal case).

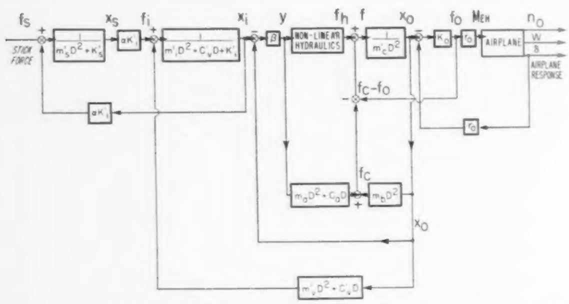


FIG. 7. Airplane with nonlinear hydraulic servo in elevator system (longitudinal case).

autopilot is shown in Fig. 11. In this case, however, the aeroelastic transfer functions (blocks) are not shown. The inner loop for the combination of missile plus autopilot is usually referred to as the "stability" loop, whereas the outer loop, which includes the entire system, is usually referred to as the "guidance" loop. These loops can couple dynamically, especially during the "close-in" phase of the missile-target trajectory.

Also represented in Fig. 11 are the axis transformation box and the missile-target geometry box. The transformation box relates body axes to path axes, and the geometry box determines the relative kinematics between missile and target.

As previously pointed out, many systems do not contain a computer, so that the signals go directly from the seeker to the autopilot. The diagram for this case would be a simplification of Fig. 11.

The computer and the radar seeker systems could also be expanded in block diagram form to show further detail. However, this procedure would be the same as that used in this paper for the airplane and the autopilot and therefore will not be demonstrated.

The "pyramiding" process, then, starts with the aircraft body modes (which are the primary objects of control) and expands progressively to include the dynamics of the medium, the multielastic structure, the aerodynamic controls, the power boost, the autopilot, the computer, the seeker, and the target.

The dynamic stability and accuracy of the system are then determined by various methods, a few of which are discussed in the next section of this paper.

(V) METHODS OF DYNAMIC ANALYSIS

Examples of fundamental analytical tools for analysis of automatic control systems are classical methods for solution of differential equations, Laplace transform methods, and methods based on Heaviside operational calculus. As customary in all branches of mathematical science, the problems of automatic control were first attacked by means of the classical methods for solution of the differential equations of motion.[3] This approach is limited, however, because of the difficulties attendant with the solution of higher order differential equations. These difficulties were partially alleviated by the use of Heaviside's operational calculus, which is basically an extension of the concept of the operator D $(=d/dt)$ used in the classical method. The methods of operational calculus were placed on a sound and rigorous basis with the development of the Laplace transform, which is now the primary analytical tool used in the analysis and synthesis of automatic control systems.[4, 5]

The utility of the Laplace transform is based on the property that the transformation integral,

$$F(s) = \int_0^\infty f(t)e^{-st}\,dt$$

transforms linear differential equations, in the time domain, into algebraic equations in the complex s-plane and simultaneously introduces the initial conditions of the problem. The resulting equations can be solved algebraically and then returned to the time domain by the inverse transformation, which is defined by the complex inversion integral,

$$f(t) = \frac{1}{2\pi i}\int_{c-i\infty}^{c+i\infty} F(s)e^{st}\,ds$$

the proper evaluation of which depends on the nature of the roots of the characteristic equation (in this case, the denominator of the solutions of the transformed equations of the system). The actual process is greatly simplified by the use of tables of transforms, which give simple time functions and their transformations to the s-plane. The transformed equations can usually be expanded in partial fractions of simple form which appear in tables of transforms, so that the inverse transformation does not require the use of the inversion integral. This partial fraction expansion, however, requires a knowledge of the roots of the characteristic equation, which are often difficult to obtain.

The Heaviside operational calculus, which was developed before the Laplace transform method, is based on the replacement of d/dt by the operator p in the differential equations of motion, which then become a set of algebraic equations in p. This set of equations is then solved algebraically, the denominator of the solutions being the characteristic equation of the system. Various operational rules, based on the nature of the roots of the characteristic equation, are used to obtain the transient response of the system. In recent times, these rules of operation have been defined in such a way that the operations are equivalent to those of the Laplace transform; in fact, many treatments of operational calculus are actually expositions of Laplace transform theory, so that many people assume that the two methods are identical. As a result, many authors have made the operational formulas of the two methods identical by defining the Laplace transform as

$$F(p) = p \int_0^\infty f(t)e^{-pt}\, dt$$

and the complex inversion integral as

$$f(t) = \frac{1}{2\pi i} \int_{c-i\infty}^{c+i\infty} \frac{F(p)}{p} e^{pt}\, dp$$

where these definitions differ from the previous ones only by a factor of p.[7]

Simultaneous with the development of the Laplace transform method of obtaining time solutions of the differential equations of motion, the concept of the transfer function (which is the ratio of the transformed output to the transformed input of the system) came into widespread use. Current procedure in the analysis and synthesis of automatic control systems makes use of the transfer function for sinusoidal input (i.e., the forced frequency response). This procedure was developed by communication engineers, such as Nyquist,[2] Black,[8] Guillemin,[9] and Bode,[10] in terms of fundamental concepts such as the Nyquist and Black theory of stability of closed-loop systems, which is based on certain properties associated with the system's open-loop ($\mu\beta$) transfer function for sinusoidal input, and the Bode theory of the attenuation frequency and phase characteristics of minimum phase electrical networks. These fundamental concepts are valuable for the analysis and improvement of existing systems and for the synthesis of new systems, thus complementing the previous methods of analysis. The application of these concepts to servomechanisms is treated in detail in the books of references 4 and 5.

Another practical method for analysis and synthesis is the root locus method,[6] which is based on the principle of sketching the locus, with gain as a parameter, of system characteristic equation roots contributed by each of the various component loops of a multiloop system, and from these loci selecting for each component loop the gain that would give the desired locations of these roots for best performance of each loop. The procedure is to start with the innermost loop of the system and work outward to include the entire system, thus synthesizing the system. Since the roots of the system characteristic equation, which are required to obtain the time solutions for the system, are determined by this procedure, the method is useful in analysis as well as synthesis of dynamic systems.

The difficulty of obtaining simple analytical expressions for the input forcing functions of many problems necessitated the development of numerical methods for obtaining the time solution. The first approach to this problem was the use of numerical integration, but the disadvantages of this method (such as extreme tediousness in its manual application) soon led to more easily applied methods. Among these are the Transfer Func-

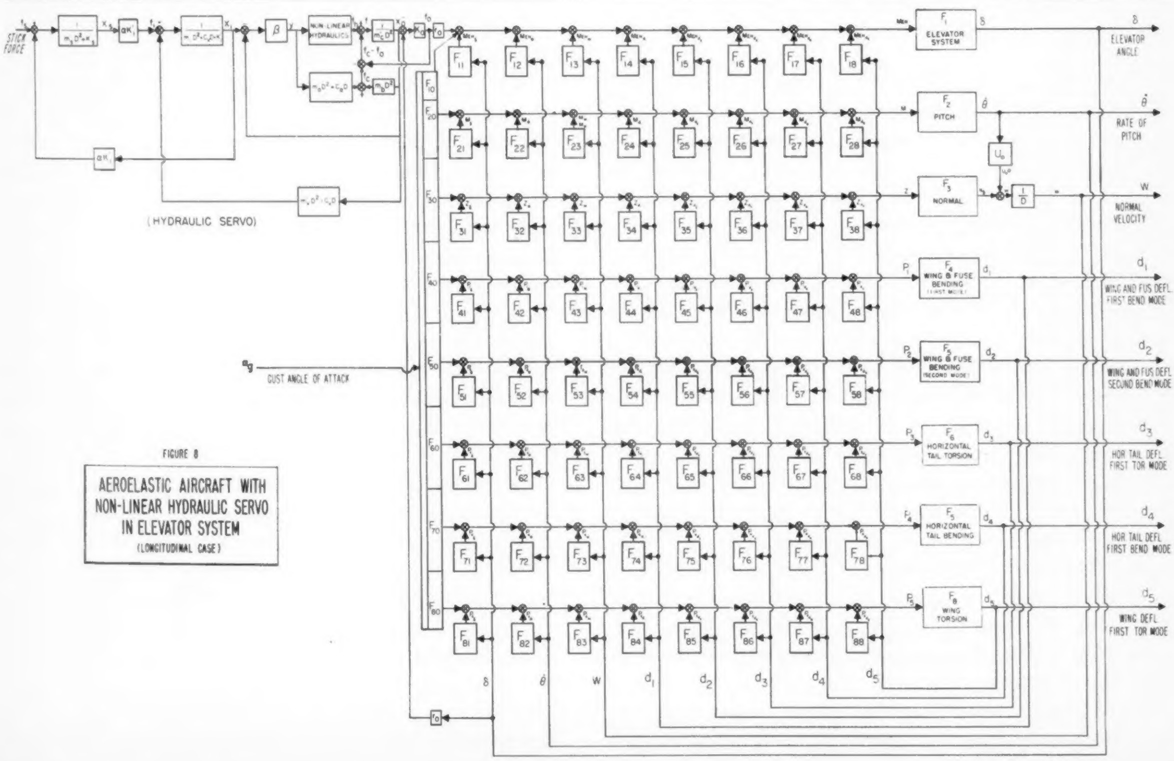


FIGURE 8

AEROELASTIC AIRCRAFT WITH NON-LINEAR HYDRAULIC SERVO IN ELEVATOR SYSTEM (LONGITUDINAL CASE)

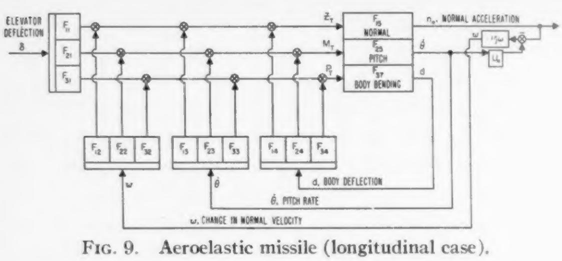


FIG. 9. Aeroelastic missile (longitudinal case).

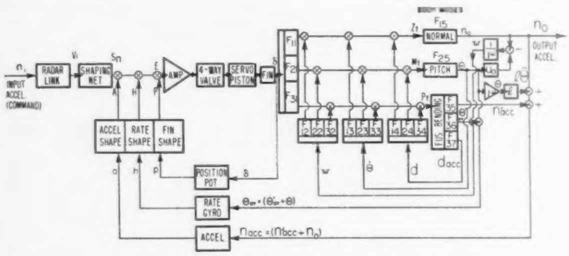


FIG. 10. Aeroelastic missile plus autopilot (longitudinal case).

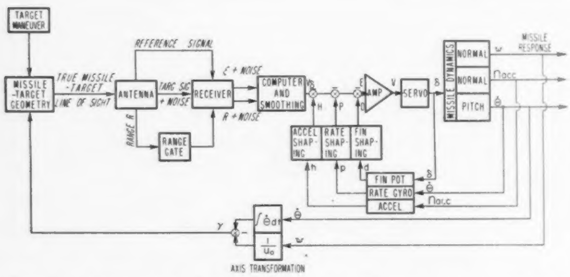


FIG. 11. Aircraft plus autopilot plus computer plus seeker plus target (longitudinal case).

tion-Fourier method,[1] and the Number Series method,[11] both of which supplement the analytical synthesis techniques based on the frequency response concepts already mentioned. These two numerical methods are also of great value in empirical (laboratory or flight-test) studies of dynamic systems.

The Transfer Function-Fourier method is based on representing the dynamics of the system in terms of the transfer function (for sinusoidal input). The transient output is then found by representing the input as a Fourier series, multiplying the amplitude and shifting the phase of each input component as indicated by the value of the transfer function for that frequency, and summing the resulting output components. It is possible to work the inverse problem—that of finding the transfer function from transient data—by expressing both input and output as Fourier series with the same fundamental frequency. The output-to-input vector ratio of terms of corresponding frequency is then the value of the transfer function at that frequency. This TFF method by-passes the necessity for determining the roots of the system.

The Number Series method is based on representing an arbitrary function by a series of overlapping fundamental building blocks, such as step-functions, ramps, triangles, etc. The operations of addition, subtraction, multiplication, division, integration, and differentiation are defined in terms of these building blocks. When applied to the solution of differential equations, the Number Series method results in the derivation of a dynamical operator (which is the response to a unit building block) which, when properly multiplied by an input forcing function (expressed as a number series), gives the time history of the output. The dynamical operator can also be derived from transient test data by the proper performance of a division process; it is also possible to reduce the dynamical operator to the transfer function for the system and vice versa. The number series method is sometimes referred to as the polynominal transform method.

Nonlinear systems cannot in general be analyzed by the above methods, with the exception of the numerical integration method (and in some cases the Number Series method). Furthermore, even the linear (or "quasi-linear") systems of the present time are becoming so complex that the manual application of the above methods to many systems is prohibitively time-consuming. Automatic computing devices are the most promising solution to this problem.

New developments in the field of automatic control have been primarily through the costly process of building and testing models, or through the experience acquired from data on actual operations of previous designs. With the ever growing demand for automatic control systems, it is important to provide simpler and more complete methods of analysis than are available by use of conventional mathematics. For this reason, several types of analog and digital calculating machines and electromechanical simulators have been developed.

Through the analogy between electrical circuits and numerous other physical systems, many important and complex dynamic problems can be solved by the use of similar electrical networks. This point of view has led to the development of an electrical (or electromechanical) analog type of computer, such as the Transient Analyzer, under the direction of McCann and others.[12, 13] This particular type of machine has proved to be especially useful for the analysis of elastic vibrations in airplane structures and for aeroelastic synthesis of the air frame itself. The type suffers, however, from limited accuracy and the necessary (and sometimes difficult) job of establishing a new analog for each problem to be solved.

A somewhat different type of analog computer is based on the properties of d.c. operational amplifiers.[14] This type of analog computer lends itself readily to the study of general dynamic problems. It is especially useful for study of the effects on the system of parameter variations (although the Transient Analyzer can also be applied to this problem). It is particularly well adapted to the simulation of a system's individual components and the interconnection (pyramiding) of these simulated components to synthesize the overall system. This type also suffers from limited accuracy. Examples of this type are the Typhoon, Meteor, Cyclone, and REAC facilities, which are among those dynamic analysis facilities most widely used today.

In addition to pure simulation, the analog type of computer may be used as a testing device. For example, in the autopilot problem, instead of simulating the entire automatic pilot by means of an equation, many of its actual components may be incorporated in the machine in such a manner that their response to typical operating conditions can be observed directly in the laboratory. In this case, the machine acts as a tester since it has only the equations of aircraft motion "patched in" and produces the proper signal for the sensing elements of the autopilot. The autopilot then reacts as it would under flight conditions, and its output signals, which are normally used to position the control surfaces, are fed back to the computer.

Digital machines, on the other hand, are based upon the mechanization of the fundamental arithmetic operations. Several machines for doing this are at the present time in service. One of the most basic of these is the IBM calculator, which, while somewhat slower than the equivalent analog machine, is more accurate and can be adapted to the solution of a wider class of problems. Another new digital machine that shows great promise is the Maddida, which does its computation in the binary system. It has many of the advantages of an analog machine but retains the accuracy of a digital machine. Numerous other machines of this type, such as the EDVAC, the BINAC, the SWAC, the SEAC, the CALDIC, the UNIVAC, and the ENIAC, are now in use or under development. Also, completely digital air-borne control systems for automatic guidance of aircraft, including digital autopilots and digital computers, show great promise for practical development in the near future.

The digital type of machine adapts itself most readily to that type of problem which requires numerical procedures. Thus, it is possible to mechanize by digital means any of the numerical methods discussed previously. Both the digital and the analog types offer much hope in the field of nonlinear mechanics. The digital type is, in general, slower but can be made to give a higher degree of accuracy.

On a comparative basis, it is apparent that at the present time the analog type of computer is a much more useful tool for the analysis of automatic control systems, especially since it lends itself readily to the synthesis problem and component testing. Possibly one of the reasons for this is that, up to the present time, the emphasis has been on the development of analog machines for the solution of dynamic problems. Digital machines, on the other hand, were originally developed primarily to cope with large masses of data and only recently have been notified and applied to the solution of dynamic problems. Due to the accelerated development program for simplification of digital computer components, as well as because of the greater accuracy of this type of computer, the future should see much greater use of digital machines for dynamic analysis. The IBM Defense Calculator, now under accelerated development, is an example of a new digital machine designed specifically for dynamic analysis work. However, it is the opinion of many that the combination analog-digital machine will eventually present the best compromise between speed and accuracy.

Once the dynamic stability and accuracy of the system have been determined, the effectiveness of the system in accomplishing its tactical objective should be investigated.

(VI) Effectiveness

The effectiveness of a system for automatic control of a weapon is measured in terms of its probability of kill. The probability of kill depends on the *accuracy* (i.e., the miss distance) of the system, the *reliability* of the system, the *lethality* of the weapon, and the *vulnerability* of the target. The lethality of the weapon, for example, depends on the warhead design, the explosive charge, the fragmentation pattern, etc., and the vulnerability of the target depends on many analogous factors.

The determination of the effectiveness of a system can be considered to consist of a further pyramiding of the work, since the effectiveness depends in part on the accuracy that must first be determined from the dynamic stability and trajectory analyses.

An effectiveness study should also include an operational sequence and tactical evaluation of the complete automatic control system. For example, in the evaluation of the effectiveness of a completely automatic interceptor system, a study should be made of the entire operational sequence, including such operational phases as the taxi, take-off, climb, enroute approach, target acquisition, tracking, fire control, return to base, landing, etc., to ensure against any operational "bottlenecks." This, of course, involves a study of the coupling between the many automatic control systems which operate in sequence within the complete system.

A complete tactical simulator for solving attrition and statistical problems associated with war games, as, for example, those associated with the multiple fighter vs. multiple bomber dual, should be a natural outgrowth of the basic work now going on in the computer and simulator fields.

(VII) Conclusions and Recommendations

The author would like to emphasize the necessity for the *systems approach* in automatic control analysis and the usefulness of the "pyramiding" process in this approach.

It has become obvious that the most practical method of analyzing and synthesizing complicated dynamic control systems is by use of machine computation and simulation facilities. The components of simulators can also be pyramided and thus used for the synthesis of a dynamic system. However, there is a serious shortage of these computation and simulation

(Continued on page 60)

Operational Aspects of Turbo-Jet Transports

R. Dixon Speas*

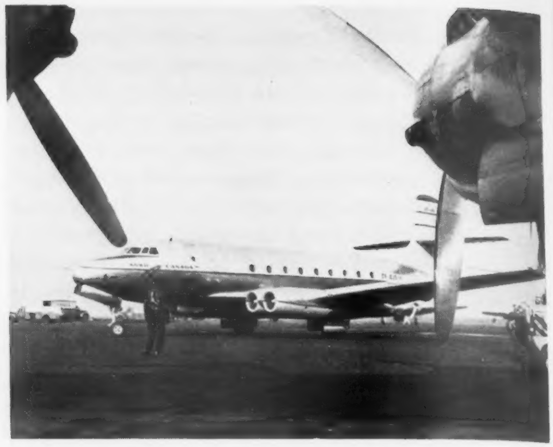


Fig. 2. Avro Jetliner C-102 photographed at LaGuardia Field after first intercity flight in the United States of a jet transport.

Introduction

Any attempt in 1951 to fully outline operational aspects of turbine powered transports is an impossible task. It is a well-known fact that major deficiencies of transport aircraft, power plants, equipment, and operating procedure deficiencies often remain undiscovered through months and years of heavy transport operations. For example, a major case of such deficiency of recent years remained undiscovered until approximately 100 of a new type transport had gone into heavy air-line utilization. Despite improvements in the science of preventative engineering, there appears no substitute for experience.

Experience thus far gained with gas-turbine power plants is not of sufficient scope to draw full conclusions with respect to transport operation characteristics. There is probably less than 5,000,000 engine hours of turbine flight operation in the world today. The air lines of the United States alone operate more than 25,000 engine hours per day. In approximately 6 months of full-scale turbine operation, the U.S. air lines would see the entire life span of turbine operation (1939 through 1951) pass before their eyes. In addition to the comparative small volume of gas-turbine experience, the type of operation is largely different in nature from transport operation. There are probably less than 100 turbine engines in the world today with more than 1,000 total flight hours. Operators are all well aware of chronic and serious power-plant difficulties that do not show up until 2,000, 3,000, or 5,000 total hours.

Despite their present embryonic status, it is generally agreed that gas turbines will become primary power plants for transport aircraft. Such a conclusion comes

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COUNTRY	AIRCRAFT	POWERPLANTS			WEIGHTS				DIMENSIONS					NORMAL CRUISING CONDITION	
		No.	Name	Type	Takeoff Thrust or HP	Takeoff Pounds	Landing Pounds	Empty Operating Pounds(1)	Span	Length	Height	Wing Area Sq.Ft.	Aspect Ratio	Altitude Feet	True Air Speed MPH (2)
United States	Chase XC-123A	4	General Electric J-47	Turbo-Jet	5200#	NA	NA	NA	110' 0"	77' 1"	32' 8"	1223	9.89	NA	NA
United States	Convair Turboliner	2	Allison T-38	Turbo-Prop	2750 HP	45,000	42,857	28,000	91' 9"	74' 8"	26'11"	817	10.0	25,000	325
Canada	AVRO Jetliner I	4	Rolls Royce "Derwent"	Turbo-Jet	3700#	65,000	55,000	40,000	98' 1"	82' 9"	27' 2"	1157	8.31	30,000	425
Canada	AVRO Jetliner II	4	Allison J-33	Turbo-Jet	5400#(WI)	80,000	65,000	41,000	98' 1"	84' 5"	27' 2"	1157	8.31	35,000	460
France	Sud-Quest So-30	2	Rolls Royce "Nene"	Turbo-Jet	5000#	37,500	NA	NA	84' 7"	61' -	NA	NA	NA	33,000	465(M)
England	Armstrong Whitworth Apollo	4	Armstrong Siddeley "Mamba"	Turbo-Jet	1320 HP + 405#	45,000	43,000	28,500	92' 0"	71' 6"	26' 0"	986	8.58	20,000	325
England	AVRO Ashton	4	Rolls Royce "Nene"	Turbo-Jet	5000#	80,000	NA	42,000	120' 0"	85' 3"	20'11"	1420	NA		
England	DeHavilland Comet I	4	DeHavilland "Ghost"	Turbo-Jet	5000#	105,000	80,000	NA	115' 0"	93' 0"	28' 5"	2015	NA	40,000	490
England	DeHavilland Comet II	4	Rolls Royce "Avon"	Turbo-Jet	6000# +	NA	NA	NA	115' 0"	93' 0"	28' 5"	2015	NA		
England	Handley Page Hermes-5	4	Bristol "Theseus"	Turbo-Prop	2820 HP	90,000	75,000	54,000	113' 0"	96'10"	29'11"	1408	9.08	20,000	350
England	Handley Page Marathon-2	2	Armstrong Siddeley "Mamba"	Turbo-Prop	1320 HP + 405#	18,000	18,000	11,000	65' 0"	52' 1"	14' 1"	498	NA	5-20,000	250
England	Vickers Viscount	4	Rolls Royce "Dart"	Turbo-Prop	1420 HP + 295#	52,500	49,800	33,200	94' 0"	81' 2"	26' 9"	963	9.17	20,000	275
England	Vickers 618	2	Rolls Royce "Nene"	Turbo-Jet	5,000#	33,500	32,500	22,000	89' 3"	65' 2"	19' 6"	882	9.0		
England	Vickers 663	2	Rolls Royce "Tay"	Turbo-Jet	6,000# +	NA	NA	NA	89' 0"	74' 6"	26' 3"	NA	NA		

Fig. 1. Turbine powered transport aircraft, prototypes of which have flown June, 1951. (1) Includes everything except fuel and pay load. (2) At weight midway between take-off and landing. (WI) Water injection. (M) Maximum.

from reams of technical analyses of performance, economics, and passenger appeal, plus the fact that the vast majority of all engine research and development in the world today is being devoted to gas turbines. As of June, 1951, installation of gas-turbine power plants has been accomplished in twelve different types of transport aircraft as shown on Fig. 1. These twelve aircraft are distributed as follows between types and home countries:

	Turbo-Jet	Turbo-Prop	Total
United States	1	1	2
England	4	4	8
Canada	1		1
France	1		1
	7	5	12

Of these twelve transports, four (two turbo-jets and two turbo-props) were originally designed for gas-turbine installation. Prototypes of these four aircraft have been flying for almost two years, and two have entered production for air-line service. Their total flight time thus far accumulated, however, is approximately the same as one that a major U.S. air line puts on its fleet in two days.

Summarizing, it can be said that as of June, 1951, sufficient transport type experience is not yet available on gas-turbine aircraft to fully analyze operating problems. At the same time, basic differences between transport and military utilization and operating requirements are so strong that no fully satisfactory basis of experience can be expected until present and proposed gas-turbine powered transports accumulate experience. Such a situation basically is no different from that that has faced any operator of a new type aircraft, and the promise of improved safety, performance, economy, and passenger appeal represented in gas-turbine powered transports supports the venture.

(1) Review of Operational Experience with Avro Canada Gas-Turbine Aircraft

The first of the two aircraft pictured in Figs. 2 and 3 is the Avro Jetliner powered by four Rolls-Royce Derwent engines. The second is the Avro CF-100 powered by two Rolls-Royce Avon engines now being replaced by two Avro Canada Orenda engines at 6,000 plus pounds of thrust each.

The Jetliner made its first flight August 10, 1949. Since that time through June 15, 1951, it has accumulated 263 hours of flight time during 199 individual flights. The airplane has been flown to an altitude of 39,500 ft.; it has flown distances of greater than 1,000 miles. The prototype has not yet been certificated, but sufficient "dry-runs" have been made to indicate ability to meet the standard performance requirements. Construction of a second prototype with greater range and higher speed abilities than the first had advanced well along into construction when priorities on Avro Canada's fighter and engine program caused a temporary halt in this program. This second prototype is to have almost 50 per cent increase in power through installation of Allison J-33 engines. The cabin pressurization system is designed to operate at a differential of 8.2 lbs. per sq.in. (gives sea level cabin to 21,500 ft.; 5,000 ft. cabin at 30,000 ft.; and 6,000 ft. cabin at 35,000 ft.). Thus far the airplane has been operated only at 4.2 lbs. per sq.in. with operation of the design value to follow demonstration of the fuselage's ability to withstand 16.4 lbs. per sq.in.

Fig. 3. Avro all-weather fighter (CF-100) in production for the R.C.A.F. at Toronto. Powered by two Avro Orenda engines.

Possibly the most interesting phase of the Jetliner's development program to date has been its cross-country flights and airport terminal experiences. Fig. 4 shows the major intercity flights that have been made, and Fig. 5 presents brief data on ten of the flights. (The flight from Chicago to New York on January 10, 1951, marked the first intercity flight of a gas-turbine powered transport within the United States.)

During and after the cross-country flights some comparisons were made between transport records and flight time of the Jetliner. It so happened that on every cross-country flight made the previous transport record was broken. The previous records set by commercial air liners were, in several instances, good because they represented the best combination of wind, weight, and power occurring during the last 3 to 4 years' operation of today's high-performance transports. The cross-country proving flights of the Jetliner were scheduled to obtain engineering data; standard cruising powers were used, and the winds were taken as found. It will be noted from the performance summary that four of the ten flights were conducted under head wind conditions, and, in one instance, both Westbound and Eastbound flights (Dayton-Indianapolis-Washington) over the same route on the same day encountered tail winds because of airflow differentials between altitudes. On another East-West combination (Toronto-Winnipeg-Toronto) effective head winds were encountered in both directions because of a shifting air mass system and the airflow direction with respect to the aircraft's course.

Through cooperation of the air lines who had flights operating at approximately the same time as the Jet-

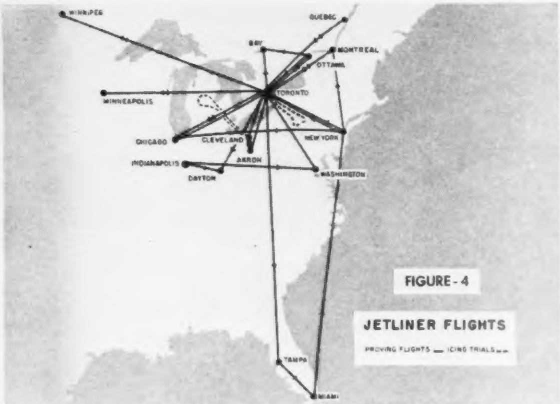


FIGURE - 4

JETLINER FLIGHTS

PROVING FLIGHTS — ICING TRIALS - -

liner intercity flights, a comparison was made between Jetliner and scheduled air-line flights as shown on Fig. 6. Comparisons were also made on fuel consumption. In the flight from Miami to New York, the Jetliner averaged 880 gal. per hour consumption compared to approximately 485 gal. per hour for a paralleling Eastern Air Lines Constellation (Jetliner over 80 per cent greater consumption per hour). Because of the speed differential, the margin of total consumption for the flight was reduced to only 33 per cent for the Jetliner over the Constellation. If a 25 per cent reduction in cost per gallon of jet fuel compared to presently used aviation gasoline is a reasonable assumption, the per mile fuel costs for the two airplanes is identical. All of which leads one to believe the oil companies must have been doing the figuring before the Jetliner made the flight.

During the cross-country flying, a three-engine ferry flight was accomplished from Chicago to Toronto. While making local flights at Chicago during November, 1950, mechanical difficulty was encountered with the No. 3 engine. Previous to the flight from Toronto to Chicago, screens had been removed from two of the three engines to guard against unanticipated icing conditions. When the fire walls were replaced after removal of the screens, one of the bolts in the fire wall of No. 3 engine apparently was not properly reinstalled. This bolt later came loose and, after some flight operations at Chicago, the bolt went into the impeller, inflicting some damage, and a washer went completely through the engine doing some damage to the exhaust turbine blades. It was decided to make a three-engine ferry flight back to Toronto with the No. 3 engine windmilling. Take-off at Chicago was accomplished on a 6,000-ft. runway with a 20-m.p.h. wind blowing at 45° from the take-off direction. Approximately a 4,300-ft. run was used for the take-off, which was made at approximately 88 per cent of maximum gross weight. After take-off, the Jetliner climbed to 22,000 ft. and cruised to Toronto at a true air speed of 370 m.p.h. Incidentally, the flight was made in substantially less time than required by a scheduled air-line flight conducted during the same time of day on four engines.

On a round trip flight from Toronto to Winnipeg, conducted January 12, 1951, the outside air temperature (after correction) was 88°F. below zero. This temperature at the cruising altitude of 35,000 ft. is the lowest yet encountered on any of the test flights. Temperature of the fuel in the wing tanks was measured during the flight with a comfortable margin maintained between the actual temperature of fuel and its coagulating temperature of approximately 45°F. below zero. At the time the flights were conducted, Electro-Thermal boots for deicing had not yet been installed. Operation of the boots would naturally decrease the lapse rate even further.

Vapor trails were observed on a number of the cross-country flights. In several instances, reports came from the ground of the vapor trails, and, on other occasions, they were sighted from the airplane through their shadow on clouds below the airplane.

It will be noted that most of the cross-country flights were conducted at 30,000 ft. and 35,000 ft. Some turbulence has been encountered at these altitudes, but by and large the air has been predominantly smoother at these higher cruising altitudes than at the 20,000-ft. and lower altitudes used in today's air-line operations.

During night operation with the Jetliner, it has been interesting to note that a passenger seated at the rear of the cabin can see no evidence that an engine is or is not operating unless he carefully notices heat-wave distortions when peering through the jet exhaust wake. Occasionally flecks of carbon from the jet exhausts under take-off, climb, cruise, descent, and power-off conditions have appeared unnoticed except by the extremely attentive observer.

Operations of the Jetliner in and about terminal airports have been particularly interesting. In addition to the Canadian ports of Toronto, Montreal, Winnipeg, and Ottawa, the prototype has operated in and out of LaGuardia, Idlewild, Chicago, Cleveland, Akron, Dayton, Indianapolis, Minneapolis, Tampa, and Miami. The Jetliner has done a large number of local flights at several of these airports, and conformation to the normal traffic pattern with other aircraft has represented no problem to the pilot or control tower operators. On the ground there have been varied receptions. At several airports, the airplane has loaded and off-loaded passengers at regular passenger loading positions. At other fields, the airport managers have directed operations to be conducted away from passenger areas, at least until the demonstrated ease of handling the airplane proved it to be no freak. Observers were continuously walking up behind the exhaust to investigate blast and heat. At high powers, the jet blast is sufficient to knock a person down similarly to the blast from a propeller. The only difference other than temperature is that a jet blast is of smaller diameter but greater velocity. The big question in most person's minds has been possible fire hazard. After a sampling of the normal blast, Ray Kelly of United Air Lines, made an observation that appears sound—"I think you'd be blown down before being scorched." Toward proving out Mr. Kelly's theory, tests were made with a flannel rag mop soaked in 100 octane gasoline. The mop was mounted on the end of a 5-ft. pole and brought as close as possible to the jet exhaust. In no instance did ignition start or threaten.

Another concern of many has been suction of the engine intake. There is no minimizing of the hazard involved without proper safeguards. It has been found, however, that routine maintenance checks can be accomplished on the Jetliner engines under idling conditions, and, at those engine powers where suction becomes a hazard, the noise warning is unmistakable. Sound recordings were taken near the air intake of a Jetliner engine. The observer and recording testified that warning came before any suction effects were noticed.

In May of this year, permission was granted by the C.A.A. of this country and D.O.T. (Department of Transport) in Canada to operate the airplane under instrument conditions. The clearance was given in order that icing trials could get under way. The aircraft has been equipped with Goodyear Electro-Thermal rubber pads protecting the leading edges of wing and tail. Although there has not yet been sufficient icing experience to prove the pads completely, flights made under light to moderate icing did provide sufficient data to reassure us of the basic excellency of Electro-Thermal deicing.

Experience with the Avro CF-100 Fighter is largely classified information. Two most important characteristics of this airplane as forecasting future commercial performance are rate of climb and descent. Demonstrated ability to climb to 40,000 ft. in substantially less than 10 min. and to descend from 40,000 ft. to 10,000 ft. in less than 2 min. is an important guide post to trends in future commercial transports.

(2) Discussion of Special Consideration Posed in Transport Operation of Gas-Turbine Aircraft

In discussing the various aspects and problems of gas-turbine applications to transport operations, it must be emphasized that the future must be expected to hold problems as well as solutions. None of the problems thus far actually encountered with gas-turbine transports or dreamed up from the side lines can be considered "stop signs." "Caution" signs, yes, because the

				Takeoff to Landing			Airline Flights Same Time of Day	
	Mileage Flown	Cruising Altitude	Cruising Airspeed	Avge. Wind	Hr. Min.	Avge. Speed	Hr. Min.	Avge. Speed
Toronto to Tampa (1-22-51)	1113	35,000'	425 mph	+ 3mph	2:58	375mph	5:10	215 mph
Miami to New York (1-25-51)	1100	35,000'	430 to 450 mph	+76mph	2:29	443mph	3:24 3:16	324 mph 337 mph
Toronto to Winnipeg (1-12-51)	961	35,000'	428 mph	-19mph	2:39	363mph	4:48	200 mph
Winnipeg to Toronto (1-12-51)	961	35,000'	432 mph	-17 mph	2:33	378mph	4:32	212 mph
Chicago to New York (1-10-51)	745	30,000' to 35,000'	430 mph	+75mph	1:49	410mph	2:34 2:35 2:37	290 mph 288 mph 285 mph
Indianapolis to Washington (3-11-51)	525	33,000'	430mph to 450mph	+75mph	1:15	420mph	--	--
Toronto to Chicago (1-10-51)	457	30,000'	430mph	-45mph	1:31	300mph	2:45	166 mph
*Chicago to Toronto (11-27-50)	*520	*22,000'	*370mph	+5mph	1:40	313mph	2:10	235 mph
New York to Toronto (1-10-51)	361	30,000'	430mph	-43mph	1:07	323mph	2:09	168 mph
Dayton to Indianapolis (3-11-51)	120	10,000'	400mph	+20mph	:19	330mph	--	--

*FLIGHT CONDUCTED ON 3 ENGINES INCLUDING TAKEOFF, CLIMB, CRUISE, DESCENT & LANDING. EXTRA 63 MILES (OVER 457 DIRECT) BECAUSE OF AIRWAYS TRAFFIC ROUTING.

Fig. 5. Performance summary of proving flights of the Avro Jetliner.

	Parallel Flights Compared		Takeoff to Landing Elapsed Time			Takeoff to Landing Average Speed		
	Number	Average Distance	Airliner Hrs. Min.	Jetliner Hr. Min.	Time Saved Hr. Min.	Airliner	Jetliner	Speed Increase
Airliner A	3	863 mi.	8.25	6.07	2:18(27%)	308 mph	423 mph	105 mph (34%)
Airliner B	2	923 mi.	6.01	4.18	1.43(28%)	306 mph	429 mph	123 mph (40%)
Airliner C	5	770 mi.	19.24	10.48	8.36(44%)	200 mph	357 mph	157 mph (78%)

FIG. 6. Performance comparison of Jetliner to air-line flights. Operated on regular schedule at approximately same time of day. All air liners are four-engined pressurized postwar aircraft.

only real progress in aviation is made with full acknowledgment and consideration of problems—real and potential—which might be involved. Just as surely as other problems will arise with experience, however, the experience is required to demonstrate the problems.

Cruise Control

Final determination of cruise-control procedures must depend upon the combination of aircraft and engine. Early generalized conclusions based on one specific combination may tend to be misleading. Several observations with respect to cruise-control fundamentals, however, do appear to be in order at this time.

Both the turbo-prop and turbo-jet powered transports are more sensitive, fuel consumption-wise, to altitude change than reciprocating powered transports. Fig. 7 shows fuel consumption data for the Jetliner compared to 1951 reciprocating powered transports. It can be seen that consumption per mile for the jet increases 87 per cent for a 20,000-ft. decrease in altitude. For the reciprocating powered transport, shown best in this respect, a 20,000-ft. decrease in altitude brings only a 20 per cent increase in fuel consumption per mile. Corresponding calculations for a turbo-prop shows a 25 per cent differential for a 10,000-ft. decrease in altitude. (See Fig. 8, based on a two-engined transport with alternate installations of reciprocating and turbo-prop power plants.) At their altitudes, however, on a cost per mile basis, the turbo-jet and turbo-prop give a much better accounting for themselves than is generally acknowledged.

The problem of stacking and holding in a traffic control pattern has been featured as a gas-turbine problem, especially for the turbo-jets. The ability of jet engines to be shut off with resultant fuel savings and no concern of the passenger is helpful in this respect. In a traffic holding pattern at 5,000 ft. for example, the Jetliner as shown on Fig. 9, effects a 22 per cent savings in fuel consumed per hour. It can also be seen that the airplane has the same endurance at 5,000 ft. on two engines as is possible at approximately 23,000 ft. on four engines. Restarts in the air appear to be a normal operating practice for the experimental present and operational future.

The higher speed transports tend to become limited more often by Mach Number ratings than by power limitations. Under such circumstances an aircraft limited by Mach Number rating is slightly faster at 20,000 ft. than it is at 35,000 ft., even though the fuel consumption per mile is substantially higher at 25,000 ft. Wind differentials, therefore, can encourage a Mach Number limited transport to fly at a lower altitude on occasion. For example, with a 150-m.p.h. head wind at 35,000 ft. and a 75-m.p.h. head wind at 25,000 ft., a 450-m.p.h. transport would require approximately 40 min. (25 per cent) longer flight plan over a 1,000-mile flight, at the 35,000-ft. level, compared to the 25,000-ft. level. The fuel consumption might be higher at 25,000 ft., but the overall economics, as well as importance, of schedule dependability would favor the lower altitude. In addition to taking advantage of wind differentials, the increased "Altitude Availability" of turbine powered transports should be valuable in increasing the airplane's flexibility of operation in meeting icing, turbulence, and other meteorological conditions.

One primary advantage of the faster gas-turbine aircraft is that they are less sensitive to wind velocity variations and thereby allow more accurate flight plan forecasts and better schedule regularity. A comparative example is shown in Table 1.

Airways Traffic Control

On first blush of turbo-jet transport operation consideration, many waving hands went into the air, and it was said many times that traffic control procedures would have to be drastically changed before any turbo-jet operation would be practical. It is undoubtedly true that the effectiveness of turbo-jet transports, as well as reciprocating powered transports, can be greatly increased with the improvements planned and undergoing installations in the airways traffic control system

TABLE 1
Chicago to Los Angeles (1,750 Miles)

	Air Liner A	Jet Transports B	C
Cruising speed	300 m.p.h.	450 m.p.h.	550 m.p.h.
Cruising altitude	20,000 ft.	30,000 ft.	30,000 ft.
Wind forecast	−50 m.p.h.	−70 m.p.h.	−70 m.p.h.
Flight plan	7:12	4:46	3:49
Wind actual	−75 m.p.h.	−105 m.p.h.	−105 m.p.h.
Actual flight time	7:58	5:13	4:06
Flight plan error	:46	:27	:17

of this country. It cannot be said, however, that operation of the jet transports must await implementation of a traffic control improvement program. The first concern usually expressed as to operation of turbo-jet transports with the existing airways traffic control system is with respect to fuel reserves. The general approach being taken in 1951 in turbo-jet route analyses is that sufficient fuel reserve must be provided consistent with today's operating practices. Such an analysis is always a bitter pill to the aircraft engineer who sees the potential applications of his aircraft substantially increased if fuel reserves are cut back. The fact of the matter is, however, that even with 1951 operating fuel reserve practices the turbo-jet can be reasonably applied to major air routes of all continents, including those in the United States.

Of positive aid to the airways traffic control problem is the climbing and descending rate of the turbo-jet powered transport. Figs. 10 and 11 show comparative patterns for climb and descent plotted against both time and distance. Under typical operation conditions of the jet transport versus the present-day reciprocating powered transport airplane, it will be noted that the jet transport is up to the 10,000-ft. level in 5 min. and 20 miles after take-off as compared to 13 min. and 40 miles for the reciprocating powered transport. In descent, the jet transport leaves cruising altitude only 16 min. and 80 miles from destination as contrasted to the reciprocating powered transport leaving its 20,000-ft. cruising level 31 min. and 160 miles from destination. The use of dive brakes is important in making the descent possible; the practice is made allowable by the high pressure ratio maintained between cabin and outside pressures.

In view of the advantages of rapid rates of ascent and descent not only for airways traffic control purposes, but also to improve passenger comfort, increase performance, and reduce costs, it can be expected that continued progress will be made toward increased rates of climb and descent.

It can be seen that the performance abilities of the airplane should provide much greater flexibility to the airways traffic controller in his routing of aircraft for minimum interference. In view of the jet transports' inherent speed advantages, airways traffic control congestion should be reduced insofar as the elapsed time, rather than elapsed mileage, is a factor of consideration.

Concerning airways traffic control, the third point in favor of speedier aircraft is their ability to "get where they are going before the weather has had a chance to change." It is obviously true that the shorter the time from forecast the more accurate will be the weather prediction. In other words, if a pilot takes off from Miami at noon with a 4-hour flight plan to New York, he will be less sure of what the weather will be at New York upon arrival than a pilot who takes off at 1:00 p.m. with a 3-hour flight plan.

FUEL CONSUMPTION DATA
JET AND RECIPROCATING POWERED TRANSPORTS

	JET TRANSPORT CRUISING SPEED - TRUE AIRSPEED										RECIPROCATING POWERED TRANSPORTS		
	500 MPH		450 MPH		400 MPH		350 MPH		300 MPH				
	Miles/ 1000#	Cents/ Mile	Miles/ 1000#	Cents/ Mile	Miles/ 1000#	Cents/ Mile	Miles/ 1000#	Cents/ Mile	Miles/ 1000#	Cents/ Mile	True Airspeed	Miles/ 1000#	Fuel Cost/Mile Cents
35,000 Ft.	79	25.2	86	23.2	89	22.5	88	22.8	--	--	--	--	--
30,000 Ft.	66	30.2	74	27.0	79	25.4	81	24.7	--	--	--	--	--
25,000 Ft.	57	35.0	63	30.6	68	24.4	74	27.0	--	--	A-335 B-304 C-325	103 136 145	32.4 22.2 20.7
20,000 Ft.	50	40.0	55	36.4	60	33.4	63	31.7	64	31.2	A-320 B-293 C-315	99 131 140	33.8 22.9 21.4
15,000 Ft.	41	48.9	46	43.5	51	39.3	54	37.0	56	35.7	A-305 B-282 C-295	94 126 132	35.5 23.8 22.7
10,000 Ft.	--	--	--	--	--	--	--	--	--	--	A-290 B-270 C-285	87 121 127	38.4 24.8 23.6
5,000 Ft.	--	--	--	--	--	--	--	--	--	--	A-275 B-259 C-270	82 116 121	41.0 25.8 24.8

FIG. 7. Fuel consumption data for jet and reciprocating powered transports.

FUEL CONSUMPTION COMPARISON
TWO ENGINED TRANSPORT
TURBO-PROP VS RECIPROCATING POWERPLANTS

Aircraft	Range	Altitude	Block to Block Speed	Fuel consumed per 100 Miles Pounds	Gallon	Dollars	Fuel Cost per Passenger Mile (1)
Turbo-Prop	200	5,000	320	895	133	$18.00	$.0069
	200	10,000	310	815	121	16.30	.0063
	200	20,000	300	714	106	14.30	.0055
Reciprocating	200	5,000	254	517	86	15.40	.0059
Turbo-Prop	1000	15,000	340	671	100	13.50	.0052
	1000	20,000	337	598	89	12.05	.0046
	1000	25,000	334	536	80	10.80	.0042
Reciprocating	1000	15,000	244	452	75	13.60	.0052

(1) Based on normal seating capacity at 65% load factor.

FIG. 8. Fuel consumption comparison of two-engined transport. Turbo-prop vs. reciprocating power plants.

Cruising Altitude	Four Engines	Three Engines	Two Engines
2,000 Ft.	5450#/Hr.	4800#/Hr.	4150#/Hr.
5,000 Ft.	5150#/Hr.	4550#/Hr.	4050#/Hr.
10,000 Ft.	4750#/Hr.	4250#/Hr.	3850#/Hr.
25,000 Ft.	3950#/Hr.	3750#/Hr.	3650#/Hr.
35,000 Ft.	3600#/Hr.	3600#/Hr.	—

FIG. 9. Fuel consumption data for Avro Jetliner under holding condition at speed for maximum endurance plus 18 m.p.h. at maximum landing weight.

Ground Operations

The first jet aircraft to be seen around airports were fighter aircraft, with tailpipes relatively close to the ground and in some instances afterburning in regular use. It is natural that there should be considerable concern expressed as to possible damage to ramp areas surrounding terminal buildings and moveable equipment. Actual operating experience with the jet transport planes, however, indicates a minimum of unique ground operating problems. With reasonable care in operating practices, the jet transport appears suited to transport service without drastic changes in present-day transport procedures.

It has been mentioned that the Jetliner made approximately 50 flights on or off 10 major terminals in the United States, plus well over 100 flights from 4 major terminals of Canada. A number of the flights was made with ramp operations conducted in close proximity to other aircraft without any incident of damage from the jet blast during these ramp operations. There was experienced some local erosion of a macadam ramp at Toronto where frequent run-ups of the engines were conducted for a substantial period of time at full power output. Erosion of ground at runway ends has also been noted where heavy operation of jet fighters had been conducted. From operating experiences and analysis, several tentative conclusions appear reasonable concerning ground operation of jet transports.

(1) For normal taxiing, take-off, and landing there is no apparent erosion effect from the jet blasts. Such a conclusion may, of course, be varied according to the height of the jet exhaust from the ground surface.

(2) In those areas where full power engine run-ups are operated, such as run-up ramps and end of runway, there can result gouging out of asphalt and other black-top surfaces. In these particular positions, it would appear that maintenance in the form of patching would be necessary unless concrete surfaces were used. However, it may well be that some surfacing processes toward providing a harder surface top may properly condition the asphalt or black-top without the necessity for heavy maintenance.

(3) Maneuvering of jet transports in close proximity to passenger terminals appears practical. Just as propeller driven aircraft must be tractored into some loading positions, the jet transports must also suffer this ignoble and time-consuming operation to utilize the more cramped loading positions. The fact that the "jet blast" from the jet transport is of higher velocity through greater cross-section area than the "jet blast" from propeller driven aircraft may require somewhat more tractoring into loading positions. A promising solution for the awkward airplane parking problem of all transports is shortly to go into service proving operations by Avianca in South America, known as the "Loadair," manufactured by the Whiting Corporation. The equipment "docks" the airplane without necessity of the normal accompaniment of tractors, ramps, carts, and trucks usually required for ground handling operations.

(4) Blast effects from operation of jet transports are not serious under reasonably careful operation. Any student of air transportation has witnessed "blasting" of passengers and spectators by careless handling of a propeller driven aircraft. This blasting sends dirt, gravel, and other objects swirling through the air with uncomfortable effects on all in the way. In addition to the passenger terminal problem, run-up areas for present-day transports have their blasting problems. Blast fences are currently in use for propeller driven aircraft at several major commercial terminals. These fences, in effect, shield nearby areas from the propeller blast. Proper handling techniques for jet transports, as well as propeller driven aircraft, will minimize the "blasting" problem.

(5) The front end of a jet engine must be treated with respect just as the propeller area of a present-day transport must be considered with respect. Accidents have happened and, unfortunately, continue to happen with propeller driven aircraft when proper respect is not given to the potential hazard of propeller blast and of accidental encounter with the propeller itself. Such potentially hazardous conditions demand adequate procedures and constant training of personnel. Corresponding problems of the jet transport would appear to represent approximately the same need for careful attention. The warning through high-frequency whine of turbine when turning at sufficient speed to represent a suction hazard is consistent with reciprocating engine and propeller noise. The lack of visual warning, how-

ever, becomes significant when more than one jet aircraft is involved in ramp operations. In other words, one must assume that any jet aircraft in sight on a ramp might be in operation when the general turbine whine is in evidence.

(6) There have been proposals of towing jet aircraft to the end of the runway in order to conserve fuel consumption. In the jet aircraft in its present-day stage of development, it is true that the aircraft has a high rate of fuel consumption under taxiing conditions. Modern air-line practice, however, does not count the weight of the aircraft at the ramp, but rather makes allowances for the amount of fuel consumed during taxiing and take-off run before the wheels leave the ground. For normal airport operation, there would, therefore, appear no particular need for towing the airplane to the end of the runway. Such an airplane towing maneuver would surely cause more terminal operation trouble than any foreseeable benefit. An economic analysis of jet transport operation shows the normal cost of fuel for taxiing to be less than the overall operating cost of the reciprocating powered transport holding at a runway while running up each engine before take-off. A jet transport is ready for take-off as soon as all four engines are turning up to speed. The normal practice is to taxi to the end of a runway, put on brakes, open "Throttles" (fuel control levers), and as soon as engines are up to speed, release brakes and take off.

(7) Simultaneous starting of all engines will probably be practiced. Axial flow engines require up to 2 min. to get up to idling speed; centrifugal engines require up to 30 sec. Although special electric provisions will be required for the simultaneous starting, it would appear required unless the starting times are substantially reduced. Eight minutes are unacceptable, as well as unnecessary, for aircraft ramp starting time.

(8) Runway length requirements will be consistent with available lengths of major airports. Actually the existing jet transports of 1951 require less runway length than two widely used 4-engined standard transports of 1951.

The *de Havilland Gazette* makes the following observations concerning ground handling aspects of the "Comet" operational experience.

"Experience with the Comet at Hatfield and other airports in Europe and Africa has served to dispel certain misgivings regarding the ground handling of large jet aircraft. The Comet can taxi slow or fast and can maneuver on the ground in the same manner as propeller driven aircraft, and it can if desired be taxied on two engines. The normal taxiing speed is about 30 m.p.h. and the thrust required for starting from rest is not excessive. The amount of fuel used to taxi to the take-off point can be allowed for and need not be included in the take-off weight. The use of tractors for towing, which has been suggested as an alternative to taxiing the aircraft under its own power, does not seem necessary; the process would be slow and inconvenient and would in itself tend to create a traffic problem on busy airports.

"The concrete apron and the runway at Hatfield have shown no sign of deterioration from the effects of

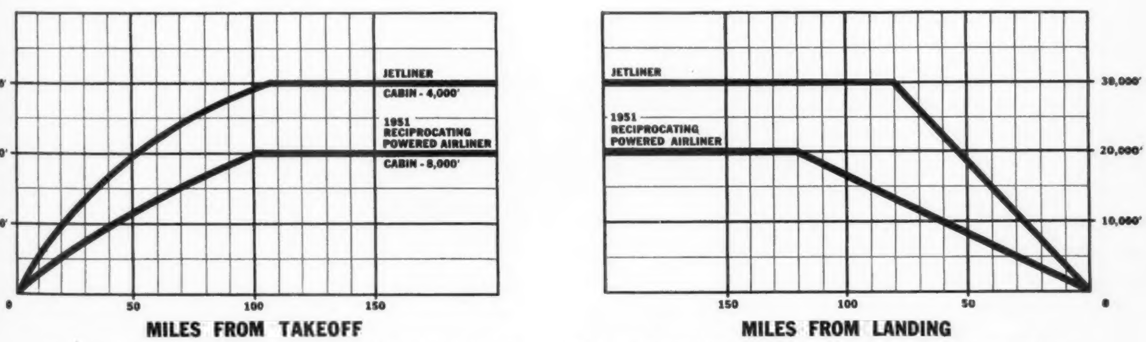


Fig. 10. Climb and descent flight paths for Jetliner and 1951 reciprocating powered air liner. Altitude vs. miles.

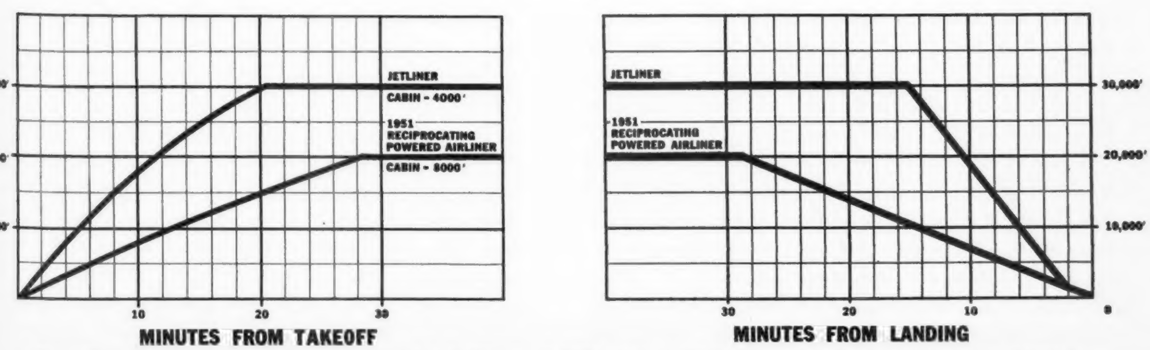


Fig. 11. Climb and descent flight paths for Jetliner and 1951 reciprocating powered air liner. Altitude vs. minutes.

jet blast. Similarly, tarmacadam runways, which are apt to suffer considerable damage by some of the smaller jet fighters, are not affected by the Comet, due to the horizontal thrust line and the large ground clearance of the jet pipes. Spillage of kerosene has caused some breakdown of the bitumen filling between the concrete slabs, but this is no new problem because petrol has the same effect.

"The air intakes on the Comet are over 7 ft. from the ground, and it is possible to walk below them in perfect safety (holding your hat) while the engines are running. The height of the intakes from the ground coupled with the robustness of the centrifugal impeller makes the use of intake guards unnecessary for ground running, although wire mesh screens are normally used while the aircraft is in the hangar to prevent tools, cats or other objects being left in the intakes."

Engine Overhaul Requirements

It is believed that the most important problem facing gas-turbine application to transport operations is the frequency of engine overhaul presently required. Although gas-turbine overhaul limits in 1951 are up to 500 hours and higher, it would be difficult at present to anticipate more than 200 hours between overhauls as an average accomplished operation. The majority of the engines just do not get to their limit. Either parts failures or modification requirements usually catch even the most advanced type engines at or before the 200 hour limit. It is true that the nature of military service does not lend itself to high utilization between overhauls; parallel overhaul lines of reciprocating and turbine engines give evidence of these facts. By the same token it is difficult to visualize substantial improvements in the overhaul picture until actual or simulated transport operations with gas-turbine engines are undertaken. A second case for concern in the consideration of turbine overhaul in transport operation is the previously mentioned small amount of experience with engines beyond the first or second overhaul period. The air lines have been badly mistaken on this one before. In one instance, an engine that had a marvelous maintenance record in military service went into commercial operation and gave a relatively good accounting for itself through the first and second overhaul periods, after which distress calls went out to the engine manufacturer to fix this, and this, and this that couldn't make the third and fourth overhauls. True, when an air-line engine of today reaches the 15,000-hour mark there may be little left but the nameplate from the original engine. At the same time, however, many parts pass 10,000 hours, and most parts get by 5,000 hours. The air lines will look long and carefully at engine overhaul records before they can conclude as to what overhaul costs can be expected. It appears that such experience will not come until transport experience is actually undertaken, because normal military combat service does not result in high utilization. Training activities may become a source of high utilization for gas-turbine overhaul data—but hardly at air-line standards. An average air-line engine will receive about 1,800 hours of flight time per year. Costs per overhaul on eighth, ninth, and tenth overhauls therefore become of early concern.

Cabin Pressurization

Turbine powered aircraft can be expected to maintain substantially higher cabin pressure differentials and fly at higher altitudes than is present air-line practice. At the same time benefits of pressurization toward improving passenger comfort in any type of transport aircraft are such that high cabin pressure differentials can be expected. With the present pressurized differentials, which are in the vicinity of 4.2 to 4.5 lbs. per sq.in., there have been a number of incidents of local structural failures in pressurized aircraft which have made the air lines understandably extremely cautious in considering plans to increase the pressure differential. Any increase in the pressure ratio, and it appears that the ratio must be immediately doubled to over 8 lbs. per sq.in. to allow efficient gas-turbine operation, must be accompanied by the most careful design treatment with all portions of the airplane fuselage. In the past days of unpressurized aircraft, the airplane fuselage has not been the critical structural item as has been the wing. With the advent of pressurized fuselages and the now demonstrated results of inadequate structural and design safety margins, the pressurized fuselage must be put in the same category as the aircraft wing insofar as safety factors, design, construction, and materials are concerned. The factor of design detail is extremely important in this respect. For example, there are believed to have been more people lost "over board" through the malfunctioning of a door in a presently used unpressurized aircraft then there have been lost "over board" from all pressurized transport aircraft. With proper attention to design detail, the problems of operating at 8 lbs. per sq.in. and higher do not appear unreasonable. Fig. 12 shows the historical trend in pressurization of transports and a possible future step.

Turbo-Prop Versus Turbo-Jet

In every new phase of aviation a series of technical competitions seem to develop. In the past such controversies have included: Biplane versus monoplane, fabric covering versus metal covering, liquid-cooled engines versus air-cooled engines, high-wing aircraft versus low-wing aircraft, and hydraulic controls versus electric controls.

The major controversy of the gas-turbine era appears to be turbo-props versus turbo-jets. Actually, each of the two types of power plants has unique characteristics that make each suitable for transport service. The success with which proponents of each are able to correct present deficiencies and exploit basic advantages will determine the ultimate division between turbo-prop and turbo-jet utilization in the gas-turbine era. In the foreseeable future, both will be in air-line operation.

Pro Turbo-Prop Factors

(*1*) *Lower specific fuel consumptions.*—It is basically more efficient under present engineering knowledge to accelerate a large mass of air through a comparatively small speed range than to accelerate a small mass of air through a large speed range. The turbo-prop is, therefore, more conservative of energy (fuel consumption) in accomplishing a given job of aircraft propulsion, up to the speeds at which propellers are reasonably efficient—350–400 m.p.h. estimated in 1951 with prospects of good supersonic efficiencies in future developments.

(*2*) *Lower noise level in rear.*—The additional exhaust turbine stages of the turbo-prop accomplish a certain amount of exhaust muffling. As a result the rear of turbo-prop cabins appear quieter than those of turbo-jets. The propeller noise, however, tends to balance this advantage.

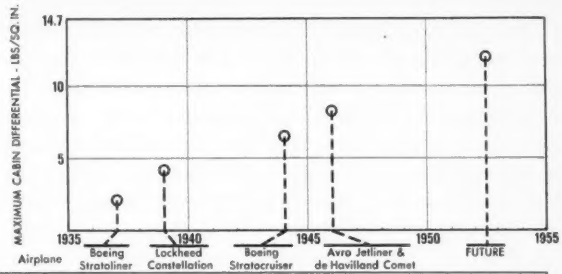
(*3*) *Greater propulsive efficiencies at low speed.*—The turbo-prop has substantially more thrust at speeds up to 75–100 m.p.h. for a given weight of engine than does the turbo-jet. The turbo-prop powered aircraft can be expected to be able to operate off shorter runway lengths than turbo-jet powered aircraft.

(*4*) *Operational aid of reversible propellers.*—One of the most important operations aids introduced in airline service during the 1945–50 period was the reversible propellers. Such a feature is possible for turbo-props but presently impossible with turbo-jets.

Pro Turbo-Jet Factors

(*1*) *Lower maintenance cost.*—The maintenance and overhaul expense of a turbo-prop can be expected to be higher than that of a turbo-jet aircraft. This cost increase goes beyond the mere labor and materials required for routine maintenance and overhaul of the added exhaust turbine stages, reduction gearing, propellers, and controls. The indirect costs and effects of the propeller inspections campaigns also add to the overall cost of operation. Although extremely difficult of evaluation, the loss in aircraft utilization, as well as the upset to normal maintenance procedures required by each of the propeller inspection campaigns, has represented in the past, and can be expected to represent in the foreseeable future, an extremely important item in the maintenance of a propeller driven aircraft. Up to 1951, the total flight experience of turbo-jet engines was so outstandingly greater than that of turbo-prop engines (see Fig. 13), that it appears reasonable to assume maintenance procedures are more fully developed for turbo-jets than for turbo-props.

(*2*) *Less noise and vibration.*—The turbo-prop powered aircraft cannot be expected to be as comfortable forward from a noise or vibration standpoint as a turbo-jet aircraft. As has been said, a turbo-prop power plant is merely a turbo-jet with the addition of propeller shaft, gearing, and propellers. It follows that additional vibration can be expected from the gearing and propeller. The full jet blast tends to balance this advantage.



	Boeing Stratoliner	Lockheed Constellation	Boeing Stratocruiser	Avro Jetliner & de Havilland Comet	FUTURE
Minimum Cabin Altitude					
at 15,000'	8,000'	4,500'	Sea Level	Sea Level	Sea Level
at 20,000'	—	8,000'	2,500'	Sea Level	Sea Level
at 30,000'	—	—	—	4,000'	Sea Level
at 40,000'	—	—	—	6,000'	2,000'
Maximum Altitude for Sea Level Cabin	5,000'	9,000'	15,400'	22,500'	35,000'

FIG. 12. Cabin pressurization development. Transport aircraft listed are those that initially established differentials shown.

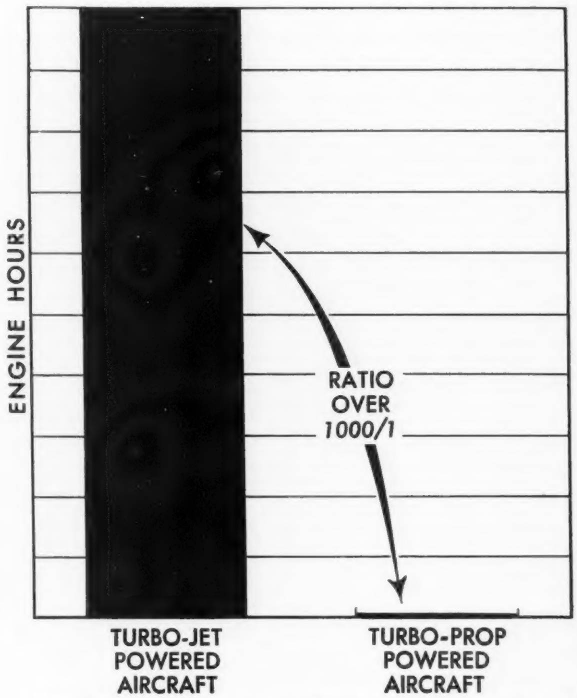


FIG. 13. Total flight times (engineering, development, and operations). Turbo-jet and turbo-prop aircraft, North American Manufacturers, 1944 through 1950.

(*3*) *Greater freedom in passenger cabin layout.*—A turbo-prop powered aircraft must necessarily compromise its interior layout because of the propeller position. In the case of the turbo-jet aircraft, the interior layout can be arranged more completely according to the interior stylist's design. The passenger cabin can start right at the front, immediately behind the cockpit, and extend back into the tail area.

(*4*) *Higher speeds.*—For at least the immediate future, it can be expected that turbo-jet transports will be faster than turbo-prop transports. Fig. 14 shows the historical record of transport cruising speeds, including present gas-turbine powered aircraft.

Passenger Appeal

The main attraction of air transportation has always been reduction of travel time. The gas-turbine engine through its ability to efficiently operate at a high altitude where the aircraft is inherently fast promises (backed by demonstrated performance) to substantially speed up air-line schedules. A history of flight times between New York and Chicago, wherein each newly introduced transport of speed advantage excited strong passenger appeal, demonstrates the potential appeal of the jet transport (see Table 2).

In addition to the speed advantage, travel by gas-turbine powered aircraft promises to be smoother and quieter. Substitution of the smooth rotary motion of a gas-turbine engine for the up and down motion of reciprocating engines represents a substantial improvement in passenger comfort through reduced vibration. It is generally agreed that the noise level inside both turbo-props and turbo-jets is less bothersome than has been the case with reciprocating powered transports.

As of 1951, the propeller plane area in turbo-prop transports and rear section of turbo-jet transports, where the jet exhaust V intersects the fuselage, still required sound proofing attention. The forward area of a turbo-jet transport and rear area of a turbo-prop transport are so extremely quiet that notice of the noisier areas is correspondingly accentuated.

When air-line flying at the 18,000- or 20,000-ft. level was generally introduced with Constellations and DC-6's, a noticeable improvement was experienced in passenger comfort through the ability of these airplanes to get over or around turbulent air. Going up to the 30,000- or 35,000-ft. level with gas-turbine powered transports promises additional improvement in this respect. Early in high altitude operation, it was feared that severe gusts might become a serious problem at the higher altitude. More complete analyses of 1951 indicate that the frequency problem is unassociated with altitude, and severity, apparently, is not unduly intensified with speed.

Despite the passenger appeal characteristics of gas-turbine transportation a careful and thorough publicity and passenger relations job must be done during the introductory days.

TABLE 2
Comparative Schedules, New York-Chicago Nonstop, 1936–1951

	Average Schedule*	Savings over Previous Equipment
DC-3	4 hours, 20 min.	
307	3 hours, 52 min.	:28 (11%)
DC-4	3 hours, 35 min.	:18 (9%)
Constellation and DC-6	3 hours, 8 min.	:28 (13%)
Jetliner†	2 hours, 13 min.	:55 (29%)

* Average of Winter-Summer and East-West times.
† As powered by Allison J-33 engines and with the same taxiing, maneuvering, run-up, and other schedule allowance as used for DC-6 schedules.

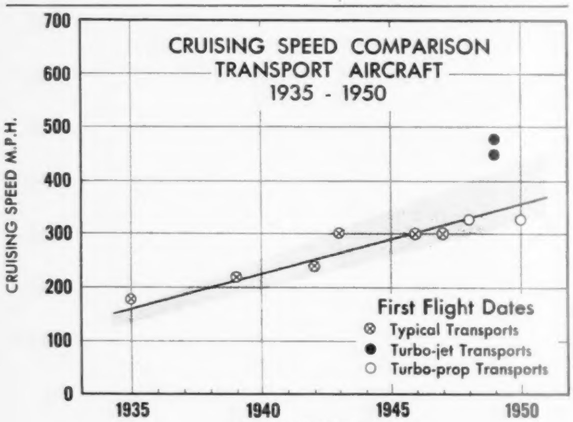


FIG. 14.

Flying Operations		
	Fuel & Taxes	$13,799,586.00 (15.5%)
	Oil & Taxes	370,136.00 (.4%)
	Other	11,054,108.08 (12.4%)
Direct Maintenance - Flight Equipment		7,554,665.64 (8.5%)
Depreciation-Flight Equipment		8,362,570.67 (9.4%)
Ground Operations		13,043,134.51 (14.6%)
Ground & Indirect Maintenance		6,823,678.18 (7.9%)
Passenger Service		6,428,277.65 (7.3%)
Traffic & Sales		8,960,084.47 (10.1%)
Advertising & Publicity		2,301,207.52 (2.6%)
General & Administrative		7,923,672.47 (8.9%)
Depreciation - Ground Equipment		2,143,479.91 (2.4%)
	Total	$88,764,591.36 (100%)
Miles flown		54,623,723

FIG. 15. Operating cost summary of the United Air Lines calendar year 1950.

(3) A VIEW OF THE AIR-LINE ECONOMICS INVOLVED IN OPERATING GAS-TURBINE AIRCRAFT

The economics of turbine powered aircraft can be studied as related to the cost breakdown for transports previously in service. Fig. 15, shows the cost breakdown for operation of United Air Lines during 1950. This cost summary is similar in percentages to those of the other major United States air lines. If the assumption were made that all of United's reciprocating transports were replaced by turbine powered aircraft, the cost factors can be divided into three groups—(a) factors that stay the same, (b) factors that decrease, and (c) factors that increase.

Any division of the factors made in 1951 obviously must be speculative. The general experience thus far gained on commercial prototype and military aircraft does appear to support some approximate forecasts.

(*A*) *Factors That Stay the Same* (*44.1 per cent*)

General and administrative (*8.9 per cent*).—The operation of fewer of the faster airplanes doing the same transportation job might be expected to require less supervision. The differential is probably insufficient to warrant recognition on a forecasting basis.

Traffic and sales (*10.1 per cent*) *and advertising and publicity* (*2.6 per cent*).—These two factors have opposing forces effecting them. The inherent speed and comfort advantages of turbine powered aircraft need less promotion, but any new step in transportation progress needs proper educational support. The competitive nature of the air transport industry is such that no decrease in the traffic and promotional budget appears reasonable.

Ground operations (*14.6 per cent*).—With the same number of aircraft arrivals and aircraft departures, this factor may be expected to remain relatively constant. The fewer number of aircraft involved with higher speeds can be expected to involve lower and some slightly lower ground operations costs.

Ground and indirect maintenance (*7.9 per cent*).—The indirect maintenance costs can be expected to be initially somewhat higher for turbine power plants and lower for the aircraft. The ground portion of these costs can be expected to be slightly lower.

(B) *Factors That Decrease* (*31.9 percent*)

Depreciation-flight equipment (*9.4 per cent*).—The turbine powered transports are basically simpler and should be less expensive to manufacture than reciprocating powered transports. Fewer of the faster aircraft are required to perform a specific transportation job, or the same number of aircraft can do a bigger transportation job.

Depreciation-ground equipment (*2.4 per cent*).—With fewer aircraft or the same number of aircraft doing an expanded transportation job this factor is improved.

Oil and taxes (*0.4 per cent*).—Turbine power plants use one or two pints of oil per hour.

Passenger service (*7.3 per cent*).—Faster aircraft require fewer meals served per mile. For example, a coast to coast passenger on a DC-3 was usually fed three meals, on a DC-6 he is served one or two meals. Most other passenger service items are either on a per mile or per passenger basis. The net result of faster aircraft should decrease passenger service expenses. The most important effect of passenger service reduction may be the resulting greater space and weight carrying capacity of the airplane achieved from reduced passenger service equipment (including buffets).

Flying operations—other (*12.4 per cent*).—The largest item in this factor is crew cost. Pilot union contracts provide additional pay for faster aircraft but not in direct ratio to the speed. A net decrease in per mile pilot and co-pilot expenses is gained with the faster aircraft. The simplicity of turbine powered aircraft forecasts elimination of requirement for flight engineer and therefore a corresponding expense decrease.

(C) *Factors That Increase* (*24.0 percent*)

Fuel and taxes (*15.5 per cent*).—Although the fuel costs on a per mile basis may be expected to be higher for turbo-jets (probably lower for turbo-props) the differential will be less than usually anticipated. The 15.5 per cent importance of fuel cost is also less than normally assumed in cost comparisons. Fuel costs are often seized upon as a 100 per cent basis of comparison merely because the factor is so positively tangible.

Direct maintenance-flight equipment (*8.5 per cent*).—Aircraft maintenance and overhaul should go down because of lessened vibration; engine maintenance should decrease because of inspection and adjustment simplicity, but engine overhaul appears to be immediately much higher for turbine power plants than reciprocating power plants. The inherent design, construction, and operation simplicity of the turbine, however, forecasts substantial improvements for the future.

In summation, this general forecast for cost adjustments attendant to transition from reciprocating to gas-turbine power plants appears as follows: factors that stay the same, 44.1 per cent; factors that decrease, 31.9 per cent; and factors that increase, 24.0 per cent.

No attempt has been made to make an exact quantitative cost analysis. A good air-line cost job requires full consideration of aircraft design and performance; route characteristics as to flight ranges; traffic demand, and hours of day utilization; as well as consideration of the air-line's basic operating practices and principles. The intent in the afore-going analysis has been to generally view the comparative magnitude of some of the cost factors that may be expected to vary.

A less tangible factor is the all important item of "passenger appeal." If the passenger appeal is as strong for the gas turbine as its proponents anticipate, the following condition could possibly ensue on competitive services even should the jet transport have operating costs initially higher.

	Seating Capacity	Schedule Time New York-Chicago	Total Cost per Mile	Load Factor	Cost per Passenger Mile
Jet Transport	50	2:13	$1.85	85%	4.3¢
1951 Transport	52	3:08	$1.75	65%	5.2¢

In addition to those factors that have been included in the analysis, some less tangible factors exist. How far reaching will be the economic effect of doing more work with the same or lesser number of aircraft? How important in aircraft maintenance is the elimination of low-frequency vibration? How soon will turbine engine overhaul times reach or exceed air-line experience on present-type engines? What will be full public reaction to gas-turbine powered aircraft? The search for answers to these questions provides the basis of interesting discussions and controversies that can go on for years. It is suggested, however, the real answers will only come after gas-turbine powered aircraft have been introduced into actual transport service. The opportunity for improved safety, increased performance, reduced costs, and greater passenger appeal promised by gas-turbine power plants to the transport field appears worthy of diligent pursuit.

Analysis of Systems for Automatic Control of Aircraft

(Continued from page 47)

facilities in the country today. Present facilities are limited, and much work remains to be done in improving their performance, expanding existing facilities, and providing new ones. The computers and simulators are analogous to the wind tunnels used in air-frame development, and a certain amount of duplication is certainly necessary.

Although analytical methods are valuable for a more complete understanding of the problem, they are limited. Manual and numerical methods are still useful in solving "*stability loop*" problems. However, for solution of the more comprehensive "*guidance loop*" problems, machine methods are mandatory.

Most of the past analytical analysis work in the automatic control field has been done for linear systems. In many cases, however, the assumption of a linear system is highly questionable or completely invalid. But up to the present time, nonlinear analytical work has resulted in solutions of a few special problems only, so that a great amount of work remains to be done in an effort to obtain a more general and practical technique for analyzing nonlinear servosystems. Here again, the most promising method of nonlinear analysis appears to be in the application of computation and simulation devices.

Many other pressing problems require immediate and extensive investigation. For example, the field of longitudinal dynamic stability of aeroelastic aircraft has been well developed, but the corresponding lateral dynamic stability field is still in the early development stages, although it is a pressing problem in airplane and missile work. Other examples of important but only partially solved dynamic problems are the coupling between conventional aircraft flutter modes and servo equipment (which has occurred to a serious degree in several recent airplane and missile systems) and the problem of determining the proper aerodynamic configuration of a missile or airplane in order to obtain an optimum automatic control system (i.e., designing the aircraft to fit the automatic control system instead of vice versa). All of these latter problems require not only extensive theoretical work but also considerable laboratory simulation work and flight testing.

In general, it is evident that the field of automatic control of aircraft is in its infancy and that a considerable amount of research and development work needs to be done before the truly efficient systems design can be attained.

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I. A. S. Previews

Summaries of Current Papers Accepted for I.A.S. Publications

Aerodynamic Coefficients of an Oscillating Airfoil in Two-Dimensional Subsonic Flow

By
R. Timman, A. I. van de Vooren, and J. H. Greidanus
National Aeronautical Research Institute, Holland

A method yielding a direct solution in terms of known functions is presented for the aerodynamic forces acting on an oscillating wing in a two-dimensional subsonic flow. The solution is based on the linearized equations of motion. Lift and pitching moment coefficients are calculated for a translation and for a rotation of the airfoil. Results are presented for five different values of the Mach Number (0.35, 0.5, 0.6, 0.7, and 0.8) and for values of ω ranging from .0.1 to 3.

Analysis of the Elastic and Plastic Stability of Sandwich Plates by the Method of Split Rigidities—II

By
P. P. Bijlaard
Cornell University

Formulas used in the first part of this paper are derived in detail. First the derivations are given of the reduction coefficients for plasticity for Cases 0 (buckling of single faces) and 1 (buckling of sandwich plates without taking account of shear deformation of core), for several cases of loading and boundary conditions. These reduction coefficients refer to the ratios of plastic and elastic buckling stresses for a given half wave length, as needed for the computation of sandwich plates. Using these expressions, some additional formulas are given for homogeneous plates, referring to the ratios of plastic and elastic buckling stresses, both computed for that half wave length that makes them a minimum. Also the buckling coefficients α of Case 2 (assuming only shear deformation of the core to occur) are derived, as far as has already been published. In the Appendix, formulas are given for application of the method to plates with anisotropic core.

The Solution of Aeroelastic Problems by Means of Electrical Analogies

By
R. H. MacNeal, G. D. McCann, and C. H. Wilts
California Institute of Technology

This paper describes a general method of mathematical analysis recently developed for aeroelastic problems. The technique permits the representation of both the air-frame elastic structure and the aerodynamic forces by electrical analogies to preserve the original physical form of the problem. Portions of the air frame that need to be represented as distributed elastic structures can be set up as finite difference equations for beams in combined bending and torsion, or, if broad short wings are involved, suitable analogies have been developed for two-dimensional plates and box structures. The physical stations for each part of the air frame are thus preserved, and the aerodynamic forces or torques are introduced at the desired stations by appropriate electric circuit techniques.

In this manner, the major portions of an air frame can be represented to a high degree of complexity, together with all important appendages such as landing gear, nacelles, and control surfaces. One important advantage of the technique is that it not only permits the analysis of complex systems but also of general studies of such systems for optimum design purposes.

On Supersonic Flow of a Two-Dimensional Jet in Uniform Stream

By
S. I. Pai
University of Maryland

It is well known that a supersonic gas jet issuing from a reservoir into a medium at rest has a periodic structure, if the difference of pressure of the jet from the medium is not large. This paper investigates a similar situation when a supersonic gas jet is issuing into a uniform stream. It is found that if the uniform stream is subsonic, the supersonic jet has *almost* periodic structure and the approximate wave length increases with the Mach Number of the surrounding stream for a given Mach Number of the jet. If the uniform stream is supersonic, the supersonic jet does not have periodic structure. The transmission and reflection of small disturbance at the boundary of the jet—i.e., a vortex sheet—are investigated. Factors of transmission and reflection of disturbances on the vortex sheet are found. They are functions of the Mach Numbers of the jet and that of uniform stream. The reflection wave may be of the same sign or of opposite sign of the incident wave or zero according to the Mach Numbers of the two streams.

Please do not order Preprints of these papers at this time.
See page 65 for Preprints that are immediately available.

Dynamic Effects in Rotor Blade Bending

By
A. H. Flax and L. Goland
Cornell Aeronautical Laboratory, Inc.

The problem of helicopter rotor blade bending moments for the case in which the blade is near resonance with one of the periodic aerodynamic forcing harmonics is considered. The additional inertia and aerodynamic damping forces due to blade bending deflection are included in the general equations for blade bending. Two methods of analysis are presented: The first is an approximate method based on the use of an amplification factor on the static bending moments of the blade, while the second is a tabular solution of the differential equation. The tabular procedure is rather laborious and time-consuming, while the amplification factor method is relatively simple. Comparison of results obtained by the two methods for a typical case indicates fairly good agreement.

Preprint No. 332

On the Deflection of Swept Cantilevered Surfaces

By
Harold C. Martin and Hemen J. Gursahaney
University of Washington

An experimental investigation is carried out for the purpose of determining the applicability of elementary theory in predicting the behavior of swept cantilevered surfaces. Attention is focused on swept plates, and primary consideration is given to deflections, although some information on stresses and dynamic characteristics is also included.

Plates with and without taper in plan form are tested at various angles of sweep. It is shown experimentally that, except in the neighborhood of the clamped edge, an axis exists which does not deflect under application of a pure twisting moment to the plate. Replacing the plate by an equivalent beam, located along this "apparent" elastic axis, permits conventional methods to be employed for calculating deflections, bending frequencies, etc. Such calculated values are shown to be in good agreement with experimental data but differ considerably from results based on the conventional elastic axis.

Preprint No. 339

On the Flight Dynamics of Slender Special Purpose Aircraft

By
R. M. Rosenberg and George Stoner
Boeing Airplane Company

In this paper, general equations of motion are derived for slender special purpose aircraft of nearly circular cross section. It is shown that considerations of steady roll and lack of circular symmetry of cross section lead to Mathieu equations. Aerodynamic force derivatives for flight not near the flutter speed are given which appear to be useful in that their application has resulted in theoretical predictions that agree satisfactorily with flight experience. Finally, some possible instabilities are discussed. The method is illustrated by an example.

Attention Members!

All members of the Institute are invited to submit material concerning their activities for publication in the "News of Members" columns of the *Aeronautical Engineering Review.*

I.A.S. Preprints

Preprints of Papers Currently Available

No.	Title	Member Price	Nonmember Price
345	The Generalized Approach to the Selection of Propulsion Systems for Aircraft—L. R. Woodworth and C. C. Kelber.	$0.35	$0.75
344	Operational Aspects of Turbo-jet Transports—R. Dixon Speas.	0.65	1.00
343	An Analytical Approach to the Fuel Sloshing and Buffeting Problems of Aircraft—H. Luskin and E. Lapin.	0.35	0.75
342	Equilibrium Temperature of an Unheated Icing Surface as a Function of Airspeed—Bernard L. Messinger.	0.50	0.85
341	Autopilot Flight Tests on the Constellation—R. L. Thoren and W. L. Howland.	0.50	0.85
340	Aerodynamic Forces Associated with Inlets of Turbojet Installations—D. D. Wyatt.	0.35	0.75
339	On the Deflection of Swept Cantilevered Surfaces—H. C. Martin and H. J. Gursahaney.	0.50	0.85
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323	Theoretical Investigation of Several Types of Single-Degree-of-Freedom Flutter—Harry L. Runyan, Herbert J. Cunningham, and Charles E. Watkins.	0.50	0.85
322	Exploratory Wind-Tunnel Investigation of Wings and Bodies at M = 6.9—Charles H. McLellan.	0.50	0.85
321	Similarity Laws for Slender Bodies of Revolution in Hypersonic Flows—Stanford E. Neice and Dorris M. Ehret.	0.35	0.75
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2 East 64th Street, New York 21, N.Y.

I.A.S. News (Continued from page 21)

ton Air Force Base, Calif. Formerly, with Northrop Aircraft, Inc.

Edward L. Cicero (T.M.), now Design Engineer, Consultants and Designers, Inc.

Dr. Hirsh G. Cohen (T.M.), Hebrew Institute of Technology, P.O.B. 910, Haifa, Israel. Formerly, Assistant Professor of Engineering Research, Ordnance Research Laboratory, The Pennsylvania State College.

Starr J. Colby (T.M.), Aerodynamicist, Santa Monica Plant, Douglas Aircraft Company, Inc. Formerly, Graduate Student.

Billy J. Cook (T.M.), Designer, Design Operations Section, Chance Vought Aircraft Division, United Aircraft Corporation. Formerly, Designer, USCO Power Equipment Corporation.

Arthur H. Croft (T.M.), Engineer, Northrop Aircraft, Inc. Formerly, Engineering Draftsman, Northrop.

Paul I. Dickey (T.M.), Aerodynamic Engineer, Consolidated Vultee Aircraft Corporation. Formerly, Aerodynamicist "B," Convair.

Joseph J. Dysart (A.F.), Project Engineer for Proposed Turboprop-Powered DC-6, Douglas Aircraft Company, Inc. Formerly, Maintenance Manager, Latin American Division, Pan American World Airways, Inc.

Wallace J. Elliott (T.M.), now Engineer, American Machine and Development Company.

REJOINS WEATHERHEAD

B. R. (Bob) Teree (A.F.) has returned to The Weatherhead Company as Chief Engineer of the Aviation Division. His previous association with this concern began in 1946 when he first came there as Project Engineer; he was later advanced to Director of Laboratories and Engineering Manager. Most recently, he was with the Hydraulic Division of The New York Air Brake Company as Director of Engineering. Mr. Teree is a graduate of the University of Michigan, having completed his work there for degrees in Aeronautical Engineering and Engineering Mathematics.

William T. Fraser (T.M.), now Design Engineer (Aircraft Gas Turbines), Allied Processes.

Dr. Hans R. Friedrich (M.), Design Specialist, Consolidated Vultee Aircraft Corporation. Formerly, Research Scientist, Ordnance Guided Missile Center, Redstone Arsenal, Ala.

First Lieutenant James R. Gannett, U.S.A.F. (T.M.), B-26 Pilot, Far Eastern Air Force Command. Formerly, Flight Test Engineer, Edwards Air Force Base, Calif.

Milton Glossa (M.), now Aeronautical Engineer for Production Control, Pilotless Aircraft, Aircraft Division (Engineering), Globe Corporation.

Captain Robert N. Green, U.S.A.F. (T.M.), now Air Force Office, Chevrolet Aircraft Engine Division, General Motors Corporation.

William K. Gulick (T.M.), Assistant Engineer in Charge of Accessory Testing, Aircraft Gas Turbine Division, General Electric Company, Lockland, Ohio. Formerly, Draftsman, Hunter Spring Company.

Raymond F. Halen (M.), Aircraft Sales Engineer, The Parker Appliance Company. Formerly, with Hydro-Aire, Inc.

James Chester Hawkins, Jr. (T.M.), Engineering Draftsman, Santa Monica Plant, Douglas Aircraft Company, Inc. Formerly, Student.

L. Joseph Herrig (M.), Fan Aerodynamicist, Joy Manufacturing Company. Formerly, Aeronautical Research Scientist, Langley Aeronautical Laboratory, N.A.C.A., Va.

Edwin H. Hiber (T.M.), Attorney-at-Law, Moss, Lyon and Dunn, 210 W. 7th St., Los Angeles. Formerly, Law Student, University of Nebraska College of Law.

Georph Horie (T.M.), now Engineering Draftsman "A," Hughes Aircraft Company.

C. R. (Jack) Irvine (M.), Assistant Division Manager and Chief Engineer, Guided Missile Division, Consolidated Vultee Aircraft Corporation. Formerly, Assistant Chief Division Engineer, Convair.

Ilia I. Islamoff (M.), General Manager, Ludwig Honold Manufacturing Company. Formerly, Superintendent, Sheet Metal, Pusey and Jones Corporation.

Read Johnson, Jr., U.S.A.F. (T.M.), Flight E, 3700th Officer Candidate Training Squadron, Lackland Air Force Base, Tex. Formerly, Junior Engineer, Engineering Experimental Station, Agricultural and Mechanical College of Texas.

Saul Knoblock (M.), Production Engineer, Production Engineering Section, Bureau of Aeronautics, U.S. Navy. Formerly, Chief Aeronautical Engineer, U.S.N. Bureau of Aeronautics Representative in Dallas, Tex.

George S. Knopf (M.), Business Manager, Research Laboratories, Bendix Aviation Corporation. Formerly, Assistant Technical Director, NEPA Division, Fairchild Engine and Airplane Corporation.

Dr. Richard H. Lloyd (M.), now with Experiment, Inc. Formerly, Project Engineer, Bell Aircraft Corporation.

Second Lieutenant Shelby O. Martin, U.S.A.F. (T.M.), Lackland Air Force Base, Tex. Formerly, Machine Operator, McCulloch Motors Corporation.

Jesse G. McFarland, Jr. (M.), Senior Designer (Missiles), Santa Monica plant, Douglas Aircraft Company, Inc. Formerly, with Tulsa Division, Douglas.

Bryan Rex Noton (T.M.), Researcher, Aeronautical Research Institute of Sweden. Formerly, Student, College of Aeronautics, Cranfield, England.

William B. O'Neal (M.), Chief Engineer, Hayes Aircraft Corporation. Formerly, Chief of Design Section, Canadair, Ltd.

Leslie R. Parkinson (A.F.), Staff Engineer, Wright Aeronautical Corporation, Curtiss-Wright Corporation. Formerly, Chairman, Departments of Mechanical and Aeronautical Engineering, Syracuse University.

Dirk N. Perper (T.M.), A Battery, 26th Field Artillery Batallion, Fort Dix, N.J. Formerly, Research Analyst "A," Santa Monica Plant, Douglas Aircraft Company, Inc.

Captain John E. Pixton, U.S.N. (Ret.) (M.), Manager, Field Engineering, Allison Division, General Motors Corporation. Formerly stationed in Washington, D.C., with U.S. Navy.

NEW APPOINTMENT

N. W. Bouley (M.) has been appointed Assistant Chief Engineer-Executive for the San Diego Division, Consolidated Vultee Aircraft Corporation. Mr. Bouley, who has been Chief Project Engineer since March, 1948, has been with Convair for nearly 15 years. He is an aeronautical engineering graduate of the University of Washington and was associated with Boeing Airplane Company while attending college and for 2 years after graduation.


From Ignition Headquarters
COMES THE
Latest and Most Revolutionary Development
IN JET ENGINE IGNITION!
Once again the Scintilla Division of Bendix sets the pace in ignition for the industry.
No longer must voltages of 15,000 be generated to break down the plug gap. This revolutionary T.L.N. system with its new shunted surface gap igniter plugs produces a hotter spark across the bridged gap with only 1000 volts.
Engine starting difficulties due to fuel-wetted plugs or carbon fouling can now be reduced to a degree previously thought impossible due to the shunted surface gap igniter plugs.
Other exclusive features include unrestricted length of small diameter, high temperature flexible leads—fewer parts—lighter weight—more concentrated energy in the spark and far greater all-around reliability and durability.
This new T.L.N. ignition system complies with all pertinent A & N Specifications, has been exhaustively flight tested and is now in production for service engines.
Complete detailed information on request.
PERFORMANCE DATA
INPUT....14-30 Volts D.C.
OUTPUT....1000 Volts D.C. to Igniter Plugs
AMBIENT LEAD TEMPERATURE....500° F
ALTITUDE....60,000 Ft. Plus
WEIGHT COMPLETE SYSTEM....6.5 lbs. Average
Bendix
SCINTILLA MAGNETO DIVISION OF
SIDNEY, NEW YORK
Bendix
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FACTORY BRANCH OFFICES: 117 E. Providencia Avenue, Burbank, California • Stephenson Building, 6560 Cass Avenue, Detroit 2, Michigan
Brouwer Building, 176 W. Wisconsin Avenue, Milwaukee, Wisconsin • 582 Market Street, San Francisco 4, California

William F. Roberts (T.M.), now Stress Analyst, Chance Vought Aircraft Division, United Aircraft Corporation.

Captain C. H. (Dutch) Schildhauer, U.S.N.R. (Ret.) (A.F.), now Vice-President and Assistant General Manager, Civil Air Transport, Inc., with Headquarters at Taipeh, Formosa.

Charles H. Seaton (T.M.), Aerodynamics Engineer, San Diego Division, Consolidated Vultee Aircraft Corporation. Formerly, Instructor in Aeronautical Engineering, The Pennsylvania State College.

John R. Stiles (M)., now Liaison Engineer, Engineering Division, Rohr Aircraft Corporation.

George D. Stilley (T.M.), Aerodynamicist "C," Aerophysics Laboratory, North American Aviation, Inc. Formerly, Graduate Student, Iowa State College.

Second Lieutenant Wallace E. Vander Velde, U.S.A.F. (T.M.), Research Engineer, Electronics Division, Air Force Cambridge Research Center, Mass. Formerly, Student.

Gene H. White (M.), Specifications Engineer, Saval Division, William R. Whittaker Co., Ltd. Formerly, Special Project Engineer, Saval, Inc.

William J. Whitehill (T.M.), Aerodynamicist "B," Aerophysics Laboratory, North American Aviation, Inc. Formerly, Junior Engineer, McDonnell Aircraft Corporation.

Corporate Member News

• **Aeroquip Corporation . . .** Two new vice-presidents of the company have been elected by the Board of Directors. Benjamin A. Main, Jr., and H. L. Schrock, Jr., have been elected Vice-President in Charge of Engineering and Vice-President and Treasurer, respectively.

• **Airborne Instruments Laboratory, Inc. . . .** Upon the occasion of the sixth corporate anniversary of Airborne Instruments on August 31, a formal ground breaking ceremony for the new Engineering and Production Division building took place. This structure, which will cost approximately $500,000 and is scheduled for completion around April, 1952, will provide an additional 50,000 sq.ft. of floor space for Airborne Instruments.

• **Allis-Chalmers Manufacturing Company . . .** The election of five new officers and the advancement of three other officers were announced on September 6. The four newly elected vice-presidents of the company are W. G. Scholl, General Sales Manager of the Tractor Division, who was named Vice-President in Charge of Sales for the Tractor Division; C. W. Schweers, Director of Sales in the General Machinery Division, who was named Vice-President in Charge of Sales for the General Machinery Division; J. F. Roberts, Director of Engineering in the General Machinery Division, who was named Vice-President in Charge of Engineering for the General Machinery Division; and W. A. Yost, Manager of the Mechanical Power Department, who was named a Vice-President of the General Machinery Division. G. F. Langenohl, Assistant Treasurer, was elected to the position of Treasurer and appointed Assistant Secretary. N. D. Johnson, Assistant Secretary, will continue to serve in that capacity and will assume additional responsibilities as Assistant Treasurer. Named as Assistant Comptrollers were E. J. Dietrich, Assistant to the Comptroller, and T. D. Lyons, Works Comptroller.

• **Aluminum Company of America . . .** Facilities at the Aluminum Research Laboratories, New Kensington, Pa., are being expanded with the construction of a new building measuring 80 by 170 ft. This new unit will increase the total floor space by about one-third and is expected to be ready for occupancy early next year.

• **American Bosch Corporation . . .** On August 29, Roosevelt Field, Inc., signed a 21-year lease with three 21-year renewal options with the Arma Corporation, a subsidiary of American Bosch. Construction of an office building with 100,000 sq.ft. of floor space and an adjoining manufacturing building containing 280,000 sq.ft. of space is scheduled for completion next April. The six large hangars now on Roosevelt Field have been leased by Arma pending completion of the new plant.

• **American Phenolic Corporation . . .** A new 65,000-sq.ft. factory building, Plant No. 4 on Chicago's west side, is to house all synthetic operations, including the molding of plastics, wire mill operations such as extruding and braiding, and is to serve as a warehouse for the supplies of materials used in these operations.

• **Bendix Aviation Corporation . . .** A new Bendix affiliate has been formed in Australia to manufacture and distribute equipment for the aircraft, automotive, and electronics fields. The new firm, Bendix-Tecnico Proprietary Limited, is jointly owned by Bendix Aviation and Tecnico Limited, of Marrickville, Australia. Bendix-Tecnico in Australia will continue to operate and will expand the former Aircraft Division of Tecnico Limited, including the latter concern's Melbourne branch. The new firm has also been designated Australian representative for Bendix International Division, the export branch of the American corporation. . . A proposal by Bendix to study, at its own expense, the commercial feasibility of manufacturing, processing, and selling radioisotopes has been accepted by the Atomic Energy Commission. The first step of the project for the wider commercial use of radioisotopes will be to study the A.E.C.'s isotope processing program and to investigate the possibilities of building and operating reactors to produce radioisotopes.

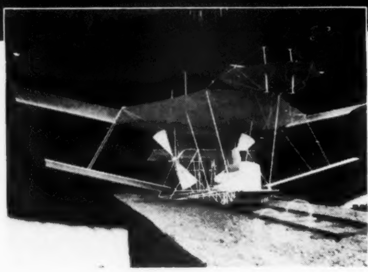
• **Boeing Airplane Company** and **General Electric Company . . .** Five colored lights, four red and one green, have been installed on the bottom of the Boeing KB-29 and KC-97 tanker airplanes to aid in keeping the two planes involved in in-flight refueling in the proper relative positions while the fuel is being transferred. The red lights indicate to the receiver pilot whether he is too far "up," "down," "forward," or "aft." The green light glows as long as the boom is extended to its proper length and correct elevation angle. The new sealed lamp, which is used in this application for both day and night in-flight refueling operations by the U.S. Air Force, was developed by G-E.

• **Boeing Airplane Company . . .** C-97 Stratofreighter flight engineer trainers and components are being built by Boeing for the U.S.A.F. Air Training

KING-SIZE TRICYCLE-GEAR AIRCRAFT GETS CROSS-WIND WHEELS

An Air Force C-54, made by Douglas Aircraft Company, Inc., became the first large airplane with a tricycle landing gear to be fitted with cross-wind wheels. Preliminary test flights were completed early in August by the Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. The C-54 used in these test flights was equipped with size 17.00-20 cross-wind wheels under a specification by the Aircraft Laboratory and built by The Goodyear Tire and Rubber Company. Further tests were scheduled as soon as the ship could be completely equipped for fully automatic flight. These tests are a part of an All Weather Flying Division program aimed at increasing flying safety under adverse weather conditions. A smaller version of the tricycle-gear airplane, Beech Aircraft Corporation's Bonanza, has been flying with Goodyear cross-wind wheels for approximately 2 years.

Aircraft engine 1894 version

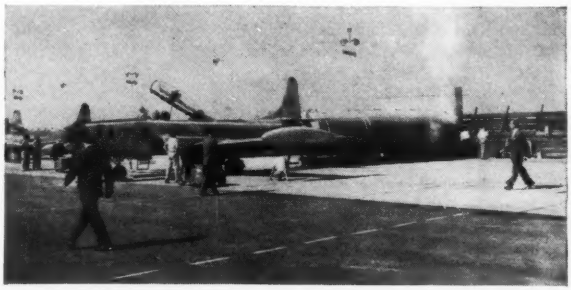


Model of the plane designed by Sir Hiram Stevens Maxim and powered by two of the engines shown above.

Sir Hiram Stevens Maxim could have left posterity a more accurate record of engine weight, but hardly a more dramatic one than the photograph shown above showing him holding one of the two 150 H. P. *steam engines* with which he powered his airplane. The airplane actually was airborne briefly on July 31, 1894. A copy of this rare engine photograph (without any advertising message) is yours for the asking.

His grandson, Hiram Hamilton Maxim, continues the family interest in aviation as head of the Company which designed and manufactured the Maxim Silencer, shown below, quieting the roar of a jet engine during run-up tests at the Lockheed plant in Burbank, California.

With 40 years of leadership in the silencing field (9 of them in the development of jet engine silencing) Maxim offers top flight research and engineering departments to solve your silencing problems, whatever they are.



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MAXIM

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Gentlemen: ☐ Please send me more information on jet engine silencing.

☐ Please send me a copy of the steam aircraft engine photo.

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COMPANY____________________

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A PHANTOM VIEW OF THE SKYROCKET

A Navy spokesman announced that on August 15 a D-558-2 Skyrocket designed and built for the U.S. Navy by the El Segundo Plant of Douglas Aircraft Company, Inc., was flown by Douglas test pilot Bill Bridgeman to an altitude that broke all existing manned altitude records, including its own. The exact altitude reached by this 45-ft. rocket-powered supersonic plane was not revealed in the statement. Shown in the accompanying phantom view of a Skyrocket are the rocket and jet engines of earlier flights. For the purposes of this August 15 flight, which marked the end of the first phase of a research and development program 3 years old, the jet engines were removed and the rocket fuel was doubled. After this particular flight was concluded, the three Skyrocket planes used in the test were turned over to the N.A.C.A. for the next phase of a planned research program.

Command and Military Air Transport Service.

• **Breeze Corporations, Inc. . . .** Three additional buildings have been acquired in the North Jersey area for both manufacturing and storage use. A new two-story structure at 41 Lincoln Ave., Orange, is to be used for production of the Breeze line of electrical connectors. The other two buildings will be used for warehousing and stock storage and are located on Route 25, Elizabeth, and on Pennsylvania Ave., Elizabeth.

• **Brooks and Perkins, Inc. . . .** A new rolling mill is being erected on a $10^1/_2$-acre site northwest of Detroit on the Chesapeake and Ohio Railroad, Pere Marquette Division main line. It will be a jobbing type mill to roll magnesium slabs into sheets of the exact sizes and gages needed for fabrication. The initial installation will include a hot mill and two cold mills with the necessary drives, ovens, and auxiliary equipment. Rolling operations are expected to begin in January, 1952.

• **Chase Aircraft Company, Inc. . . .** A Board of Directors to operate the company under the new Kaiser-Chase merger has been formed with Kaiser-Frazer Corporation and Chase each naming four men. Henry J. Kaiser and Edgar F. Kaiser are Chairman of the Board and President, respectively. Michael Stroukoff, A.F.I.A.S., of Chase, has been selected as Vice-President and Engineer and Michael Miller, a Kaiser-Frazer Vice-President, will serve as Vice-President of Chase. Other members of the board include: Jesse X. Cousins, of Chase, as Treasurer-Comptroller; William F. Sauers, M.I.A.S., of Chase, as Secretary; Eugene F. Trefethen, Executive Vice-President of Kaiser-Frazer; and Franklin S. Wood, Jr., a New York attorney representing Chase. . . The West Trenton, N.J., plant that had been used for tooling the Chase C-123 was turned back to the Navy last month for use as an electronics laboratory in conjunction with the Naval Gas Turbine Laboratory there. C-123 operations have been transferred to Willow Run, Mich.

• **Consolidated Vultee Aircraft Corporation . . .** A development contract for America's first atomic-powered airplane was awarded to Convair early in September. Convair will be concerned principally with developing the aircraft, while General Electric Company will be primarily responsible for developing its nuclear propulsion system. Both Convair and G-E will work closely with the Atomic Energy Commission and the U.S. Air Force. . . An expansion move of the Pomona, Calif., annex facilities of the Guided Missile Division, a one-story building with approximately 15,000 sq.ft. of floor area and a nearby storage lot have been leased. When the remodeling work is completed on the building now being leased for a Pomona employment office, it will also serve as an engineering annex. All of this is in conjunction with the new $50,000,000 guided missile plant now being constructed on a 140-acre site in West Pomona. The plant in West Pomona will be operated by Convair for the Navy's Bureau of Ordnance. . . A Master Planning Section has been created to determine how many B-36's can be built and how fast.

• **Eaton Manufacturing Company . . .** The 1950 Supplement of *A Chronicle of the Aviation Industry in America* is off the presses and has been mailed to the I.A.S. membership. This supplement, as in the past, was compiled by Welman A. Shrader, A.M.I.A.S., Director of Publications, Institute of the Aeronautical Sciences.

• **Edo Corporation . . .** A new seaplane beaching gear, Model 144, has been developed for handling large flying boats up to 300,000 lbs. This gear is able to submerge itself, move forward, backward, or sideways, or crawl up on to a beach on its own power-driven tread. It is propelled by two engines driving two propellers at diagonally opposite ends of the floats.

• **Globe Corporation, Aircraft Division . . .** The latest roster of officers of the Aircraft Division, now in its thirteenth year, are: President, George F. Getz, Jr.; Vice-President and Treasurer, Bruce Hightower; Vice-President and General Manager, Robert H. Wendt; Secretary, John Sandstrom; and Assistant Secretary, Elmer F. Mangold. The Directors are: George F. Getz, Jr.; James R. Getz; Harry W. Getz; Arthur R. Metz; and Bruce Hightower.

• **The B. F. Goodrich Company . . .** Now available upon request is a four-page leaflet that describes the new Inflatable Strip Seal developed for the bubble-type canopies of military aircraft used in high altitudes.

• **The B. F. Goodrich Company and El Segundo Plant of Douglas Aircraft Company, Inc. . . .** The Navy's Douglas-built AD-Skyraider is equipped with an improved pneumatic deicing system of Goodrich manufacture which is said to be more efficient in breaking ice formations and is capable of withstanding the speed of this attach bomber without lifting from the wing surface. As a result of close collaboration of the Goodrich engineers with those from the U.S. Navy's Bureau of Aeronautics and Douglas' El Segundo Plant, the expanding tubes were reduced in size to $1^1/_4$ in., the air pressure was increased from 7 to 15 lbs. per sq.in., and a solenoid manifold system was utilized to provide a pressure and vacuum for more rapid inflation and deflation.

• **Harvey Machine Company, Inc. . . .** The third unit of vertical heat-treatment equipment for high-strength extruded materials has been put into operation. These furnaces, whose heating elements are electric and are electronically controlled, are designed to hold materials to be heat treated vertically rather than horizontally. These units can heat treat extrusions over 45 ft. in length and can handle pieces up to 3,000 lbs.

• **Jack & Heintz, Inc. . . .** According to a recent announcement, it is possible to operate a solenoid 100 hours at 500°F. ambient temperature by the use of a new insulating varnish that eliminates bulky insulation in components operating at extremely high temperatures. This varnish was developed specifically for the JH 28000 solenoid, which is used on turbojet aircraft engines. Impregnating the solenoid coil with the thermosetting plastic varnish makes the coil impervious to salt spray and fungus.

• **Johns-Manville Sales Corporation . . .** A new asbestos-base, silicone-treated, high-temperature electrical insulation is now available which can be used for both interlayer and wire-wrapping insulation. Designated Quinterra Type 3, it is said to offer, among other advantages, savings on materials, a greater factor of safety, and the opportunity for more compact design of electrical devices. Quinterra Type 3 is

...with elbow swivel nut and flanged

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hose fittings

Check with RESISTOFLEX, too, for out-of-the-ordinary TEFLON and KEL-F

Processed in new equipment expressly designed to bring out optimum inertness and stability in these materials for vhf and uhf applications, and over wide temperature ranges. In uniform, homogenous rods, sheets, tubing and parts free from internal strains, cracks or porosity. Write for data.

Resistoflex now makes available the latest and long-awaited improvement in aircraft hose fitting design. Proved in jet and gas turbine engine service for over two years, this development offers you the advantages of hose fittings produced from *aluminum forgings*.

This construction allows smaller bend radii, and so saves space. Forged aluminum not only provides uniform, peak strength but also savings in weight. It assures extra resistance to fatigue. Machined with true internal bends, Resistoflex fittings minimize turbulence.

Full information and flow test data in this new catalog—*write for it today.*

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CORPORATION
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supplied in sheets, rolls, and tapes. Widths can vary from 0.25 in. to 36 in. and will be factory cut to specification. Available thicknesses are from 3 to 9 mils. This product may be combined with other dielectric materials such as mica or glass cloth. Quinterra Type 3 is a Class H insulation, as defined by A.I.E.E. standards, for service at a temperature of 180°C.

• **Lear, Incorporated . . .** Now available is the Lear Automatic Altitude Control, which, when employed in conjunction with the Lear L-2 Autopilot or other autopilots, is said to maintain an airplane at a constant barometric pressure altitude with an accuracy of ±50 ft. in an effective operating range of 1,000 ft. below sea level to 20,000 ft. above sea level.

• **Lockheed Aircraft Corporation . . .** Plans were recently revealed for a new all-cargo aircraft capable of flying coast to coast at operating costs of less than 5 cents per ton-mile and at cruising speed ranging from 300 to 336 m.p.h., depending upon the load and range. Externally, this cargo carrier, designated the L-1049B, will closely resemble the Super Constellations, now in production; internally, however, it will differ in that the design includes reinforcements and extra-sturdy fittings. Present plans call for a cargo capacity of 40,000 to 43,000 lbs. maximum with an average domestic load of 38,600 lbs. and a transatlantic load of 36,300 lbs. Production is expected for air-line use by 1952 and for military use some months earlier. Both the commercial and military versions of this carrier will be powered by four 3,250-hp. Wright compound engines, with provisions for conversion to propjet engines for a future speed of 400 m.p.h. In addition to the foregoing, Lockheed is scheduled to combine propjet and cargo facilities in another airplane. This is the L-206, which recently won an Air Force competition for a turboprop transport capable of carrying a 25,000-lb. pay load a distance of 2,000 miles. Delivery dates for the L-206, which has been designated by the U.S.A.F. as the XC-130, have not been announced. . . A $12,615,000 aircraft assembly plant is to be constructed for the Air Force at Palmdale, Calif. According to present plans, this new facility will be used for the final assembly and test flying of the Lockheed T-33, TO-2, and F-94 jet planes. Small-scale engineering and final assembly, as well as production flight tests, are scheduled to be underway at Palmdale by the end of 1952. A Lockheed hangar has already been constructed at Palmdale Airport as a jet delivery station.

• **The Glenn L. Martin Company . . .** The $5^1/_2$-ton 48-ft. Viking Rocket, built by Martin for the U.S. Naval Research Laboratory, reached an altitude of 135 miles on August 7 to set a new world's record for single-stage rockets, thus shattering the previous world's record of 114 miles held by the German V-2. The Viking's liquid oxygen and ethyl alcohol rocket engine burned for 75 sec., permitting the rocket to reach a top speed of 4,100 m.p.h.

• **McDonnell Aircraft Corporation . . .** Deliveries have been made to the U.S. Navy of what is believed to be the first jet car-

Another new development using

B. F. Goodrich Chemical Company *raw materials*

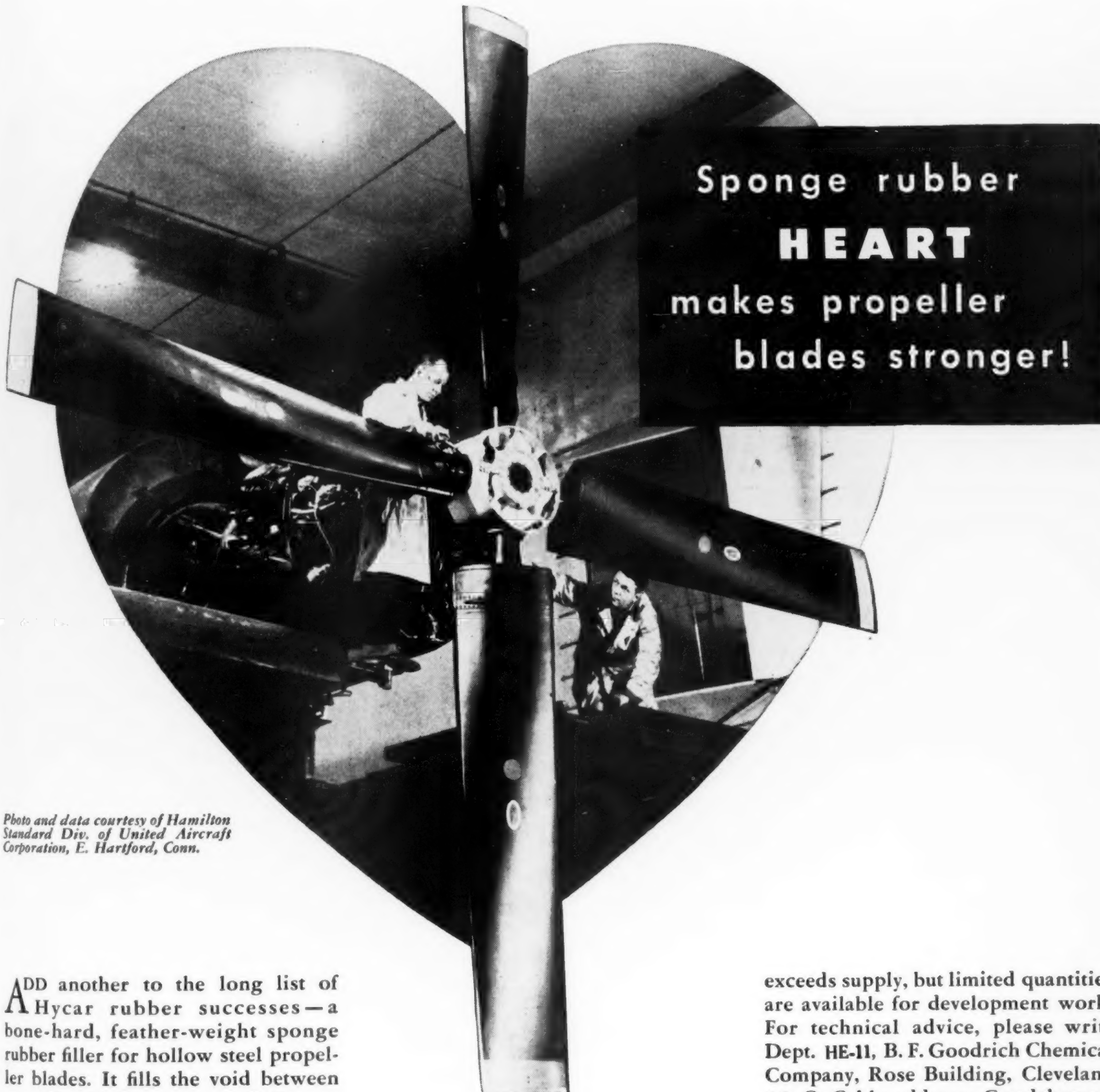

Photo and data courtesy of Hamilton Standard Div. of United Aircraft Corporation, E. Hartford, Conn.

ADD another to the long list of Hycar rubber successes—a bone-hard, feather-weight sponge rubber filler for hollow steel propeller blades. It fills the void between propeller blade core and shell, prevents the shell from vibrating in and out. It also supports the shell against the impact of rocks, ice and other material thrown up by the plane's undercarriage.

To find this filler took several years of search and tests of nearly a thousand rubber compounds. The winner contained phenolic resin, nylon, and an oil-resistant Hycar rubber compound. The presence of Hycar gives added toughness to the phenolic-nylon blend.

Hycar nitrile rubber's versatility helped make this new material possible. For Hycar has high resistance to heat, cold, cooling liquids, gas, weather and wear. It has excellent compression set characteristics, good aging properties and low moisture vapor permeability.

Hycar's advantages make it ideal for many civilian and defense products—in developing entirely new ones. Right now demand for Hycar exceeds supply, but limited quantities are available for development work. For technical advice, please write Dept. HE-11, B. F. Goodrich Chemical Company, Rose Building, Cleveland 15, O. Cable address: Goodchemco.

B. F. Goodrich Chemical Company
A Division of The B. F. Goodrich Company

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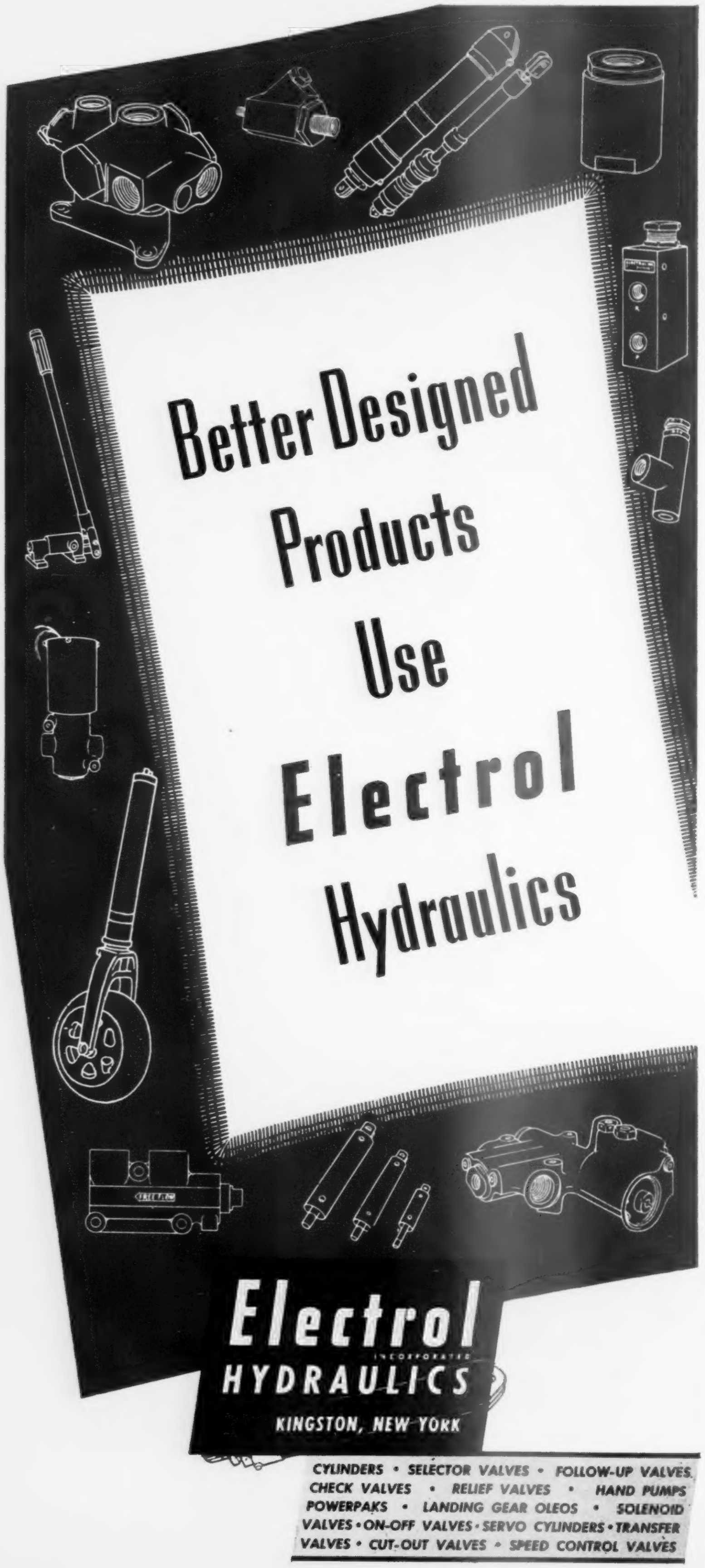
Hycar
Reg. U.S. Pat. Off.
American Rubber

GEON polyvinyl materials • HYCAR American rubber • GOOD-RITE chemicals and plasticizers
HARMON organic colors



rier-based photographic airplane ever developed. Designated the F2H-2P Banshee, the aircraft is an "offshoot" of the Navy's F2H-2 Banshee fighter and was developed through the joint efforts of the Navy's Bureau of Aeronautics and the McDonnell company.

• **Minneapolis-Honeywell Regulator Company . . .** Charles C. Buckland was recently elected a Vice-President of the company in addition to his earlier duties as Secretary. Mr. Buckland will head a newly created Subcontracting Division that will correlate and expand subcontracting activities of the Aeronautical and Ordnance divisions.

• **North American Aviation, Inc. . . .** The first of several hundred T-6G Air Force trainers to be remanufactured at the Columbus Division was successfully test flown by the early part of last September. In addition to the T-6G remanufacturing program, Air Force F-86F Sabres, Navy AJ-1 Savage attack bombers, and Navy FJ-2 Fury fighters are to be produced at Columbus.

• **Northrop Aircraft, Inc. . . .** An F-89 Scorpion recently underwent a series of five flights with the canopy removed to determine the effect of the slipstream on the aircraft's handling characteristics, on the pilot, and on the various items of equipment in the cockpit. This program was also designed to determine the limiting speed at which a radar observer, wearing presently available equipment, is capable of ejecting himself and to what extent the special Air Materiel Command Type P1-A helmet and face visor extends the tolerable speed range. There was apparently no appreciable effect on the plane's handling characteristics, the pilot, or the cockpit equipment at speeds in excess of 500 m.p.h. Furthermore, it was proved that the radar observer, using the A.M.C.-furnished visor, was able to eject himself at speeds over 500 m.p.h. . . Ground-breaking ceremonies for the new Anaheim Division building in Anaheim, Calif., took place on August 3. This new 250,000-sq.ft. plant, occupying a 34-acre site, is scheduled for completion this month. It will be used for the manufacture and assembly of precision instruments for tank range finders under U.S. Army Ordnance contract.

• **A. V. Roe Canada Limited . . .** In an effort to devise a means of speeding up materially the production of gas-turbine blades, the engineers of Avro and Modern Tool Works Limited have come up with the Tracermatic 14 Spindle Duplicator machine. As its name implies, the basic principle of this machine is that of duplicating or tracing the contours of a master-blade form simultaneously on to 14 work pieces. This is accomplished through a hydraulic tracer system. The head, carrying the tracer stylus and 14 spindles, pivots on the bearings at either end through the action of a hydraulic cylinder. The spindles themselves are driven from a common shaft by 90° skew bevel gears and each spindle can be removed for servicing. Taken all around, the Tracermatic 14 Spindle Duplicator is said to be proving invaluable for the rapid

manufacture of accurate turbine and compressor blades of complex form.

• **Simmonds Aerocessories, Inc. . . .** A new branch office has been opened in Dallas, Tex., to handle the expanding volume of aviation business in the southwest area. The offices are located in the Interurban Building in Dallas.

• **Solar Aircraft Company . . .** The development of a portable hand-started gas-turbine power plant that burns diesel oil has been announced. Created by order of the U.S. Navy's Bureau of Ships to provide a better method of fighting shipboard fires, it is also said to have many possibilities as a compact source of power for other military and civilian uses. This new T-45 portable gas-turbine-driven pump measures about 2 ft. in each dimension and provides 45 hp. with a turbine speed exceeding 40,000 r.p.m. The pump's output is 500 gals. per minute at 100 lbs per sq.in. of pressure. The Air Force refers to the T-45 as the J-2.

• **Stratos Division, Fairchild Engine and Airplane Corporation . . .** Exclusive rights in the United States for the manufacture and sale of the Orédon, a French gas-turbine auxiliary power plant, have been obtained through a license agreement with Société Turboméca. This 185-lb. unit, which delivers 140 shaft hp. for operation of accessories, is said to be particularly well suited for operation of alternators as the speed control system of the Orédon holds the r.p.m. within 0.4 per cent. This 31.7- by 20.5-in. motor develops its normal rated power at 35,000 r.p.m. and has a maximum power rating of 160 shaft hp. for 5 min. at 36,000 r.p.m. The compressor is a single-stage centrifugal-flow type with an annular air intake and a compression ratio of 3.4:1. The turbine is a two-stage axial-flow type.

• **Tinnerman Products, Inc. . . .** A new variety of Tinnerman clamp to secure bundles of wire in aircraft, heavy vehicles, or mobile units can be opened and closed without the use of tools. An interlocking slot and tongue is said to prevent the clamp from being opened accidentally. This new Wire Harness Clamp is made to be used singly or in tandem and to hold bundles $^5/_{16}$ in. to $1^1/_4$ in. in diameter and meets the maximum loading requirements for this size as set forth by the Electrical Groups in Military Aircraft.

• **Western Gear Works . . .** New construction that will increase the gear-manufacturing capacity by 30 per cent at the Lynwood, Calif., plant has been started. This is reported to be the first in a series of expansion moves planned for the Lynwood plant. A new plant is currently under construction at Belmont, Calif. A third plant is located in Seattle. Associated companies operate plants in San Francisco and Houston, Tex.

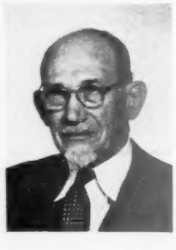
• **Westinghouse Electric Corporation . . .** Limited defense production of "confidential equipment of an electronic nature for the Armed Forces" began early in September at the new $1,500,000 Westinghouse Television-Radio Division plant in Metuchen, N.J. Original plans to use this 40,000-sq.ft. facility to triple television production have been shelved because of the international situation. . . Information on "how to select" electrical measuring instruments is found in the 30-page instrument booklet B-4696 now available. . . Edgar C. Dehne, who has been Eastern District Treasury Manager for Westinghouse, was elected Assistant Treasurer and Assistant Secretary of the corporation.

Meet Your Section Chairman

E. W. Cleveland

Cleveland-Akron Section

E. W. Cleveland, M.I.A.S., better known to the aviation industry as "Pop" Cleveland, was the guest of honor at a dinner given recently to celebrate the 40th anniversary of his first airplane solo on August 18, 1911. He currently holds an active pilot's license and during his half a century of piloting has logged something like 10,000 hours of flying time.



Looking back over the years, Mr. Cleveland recalls that in 1910 aviation was considered "a brand new means of transportation with a future that very few people believed in." Obviously, he did hold faith in the future of aviation, for he made it his life's work.

His decision in favor of an aeronautical profession first became manifest on his accepting a position in 1910 as a mechanic for Curtiss Aeroplane and Motor Company. Five years later, he left Curtiss to become an Engine Builder with Wright-Martin Aircraft Company. He remained with Wright-Martin for only a few months before he resigned to join the U.S. Army Signal Corps as a pilot and mechanic. He served as a Senior Instructor for a time before his discharge from the service in 1919.

Mr. Cleveland barnstormed around the country for 4 years and in 1923 settled down to more or less one spot in the capacity of Manager of Mayer Aircraft Company. In 1927, he became Vice-President and Director of The Cleveland Pneumatic Tool Company, a position he holds today along with those as President of Aero Engineering, Inc., and Treasurer of Air Cruisers Company.

"Being weathered in before the days of available and reliable weather information" stands out in Mr. Cleveland's memories of his 51 years in aviation. In those days, he reminisces, the "method used was to call the long-distance operator and fly or stay put according to her report."

Born in Naples, N.Y., on November 5, 1889, Mr. Cleveland attended two high schools—one in Naples and the other in Cohocton, N.Y. He married the former Lucille Wilkinson in 1918 and has one son, Lewis F. Cleveland.

Mr. Cleveland, whose avocations are hunting and fishing, is also a member of the Cleveland Ad Club, Ambassador's Club, Wings Club, City Club, and Shrine Club.

I.A.S. Sections

Buffalo Section

Hans Weichsel, Jr., *Secretary*

The last meeting of the 1950–1951 year was held on June 13. Dr. D. W. Dornberger, Director of V-2 development in Germany during World War II, presented an interesting talk entitled "The Story Behind the V-2." The speaker at this open meeting was introduced by Roy Sandstrom, Vice-President in charge of Engineering, Bell Aircraft Corporation, where Dr. Dornberger is actively engaged in missile development. Dr. Dornberger's speech was a summary of a book he is currently publishing.

Cleveland-Akron Section

Morris A. Zipkin, *former Secretary*

The results of the election of officers for the 1951–1952 year are as follows: Chairman, E. W. Cleveland; Vice-Chairman (Cleveland), Lewis A. Rodert; Vice-Chairman (Akron), Morris A. Zipkin; Secretary-Treasurer, Harrison C. Chandler.

Los Angeles Section

Milton A. Miner, *Secretary*

Two specialists meetings were held during the month of June. The first was a presentation by William D. Bell, Vice-President, Telecomputing Corporation, on June 12. His subject was "Some Digital Techniques in the Analysis of Aircraft Data."

On June 19, a panel held a meeting on the subject, "Symposium on Standardization of Thermocouple Wire Specifications." The panel was composed of representatives from the National Bureau of Standards, Air Materiel Command, Scientific Apparatus Manufacturers Association, and manufacturers and users of thermocouple wire. Because thermocouple wire is presently made to differing specifications, users of this wire

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Kidde

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Walter Kidde & Company of Canada, Ltd., Montreal, P. Q.

are constantly faced with problems of calibration, wire identification, and procurement of replacement wire. Several recent proposals have been made regarding new thermocouple wire specifications that would replace present specifications. Both the proposed specifications and the present specifications were discussed at this meeting, and an effort was made to arrive at the basis for a single standard that could be most widely acceptable.

On July 7, the Third Annual Social Mixer was held at the I.A.S. building. As a feature attraction, Zeno Klinker presented his nationally famous movie, *Man's Conquest of the Air*. Mr. Klinker, who has been Edgar Bergen-Charlie McCarthy's script writer for 14 years, delivered a running commentary during the film which had the guests "rolling in the aisles." Shown were early flights of Glenn Curtiss, Lindbergh, Doolittle, Byrd, Wiley Post, and others. Some of the party highlights included a merry-go-round system for refills in the beverage line, the conversion of the building manager's office into a nursery, and a most informal group in loud sport shirts who were totally oblivious to the usual aura of integral signs and Mach Numbers.

Philadelphia Section

Emily Dewees Rogers, *Secretary*

In addition to Mrs. Emily Dewees Rogers as Secretary, the other officers for the 1951–1952 year are: Chairman, Harris S. Campbell; Vice-Chairman, Harry Tobey; and Treasurer, LeYork Cheeseman.

Seattle Section

William L. Gray, *Outgoing Secretary*

The officers for the 1951–1952 year are as follows: Chairman, D. B. Martin; Vice-Chairman, R. M. Robbins; Secretary, R. D. FitzSimmons; and Treasurer, R. M. Carlson.

Student Branches

The Aeronautical University, Inc.

On June 12, a Bell Aircraft Corporation film release, *Planes Without Pilots*, was shown to the 28 persons present. Chairman Eugene A. Czeck presided.

A Shell Oil Company film, *How an Airplane Flies*, was shown at the June 28 meeting. Chairman Czeck presided; 22 persons were in attendance.

Northrop Aeronautical Institute

Those students currently serving as officers are: Chairman, William E. Martin; Vice-Chairman, Rustam B. Chinoy; Secretary, William J. Degnan, Jr.; Corresponding Secretary, Byron H. Fowler; and Treasurer, Roy W. DeCell.

On July 27, D. C. Gerry, Engineer for General Electric Company, spoke on "Trends and Operations of Jet-Propelled Aircraft." The meeting, attended by 26 persons, was presided over by Chairman Martin.

Riddle McKay College of Aeronautics

An election of officers was held on August 31 with the following results: Chairman, James B. Way; Vice-Chairman, William A. Gerue; Treasurer, William M. Harms; and Secretary, Richard L. Hart. The McDonnell Aircraft Corporation films, *The Navy Banshee* and *The Navy Phantom*, were shown to the 19 persons attending. The meeting was presided over by the outgoing Chairman, Morton S. Rifkin

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Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Transferred to Associate Fellow Grade

Goranson, R. Fabian, B.S. in A.E., Aero. Research Scientist, Aerodynamic Loads, N.A.C.A., Washington, D.C.

Howard, Eph, M.S.E. in Ae.E., H.D.A., Staff Aero-thermodynamicist, Engine Test Facility, ARO, Inc.

Rea, James B., Sc.D., President, J. B. Rea Co., Inc.

Wasielewski, Eugene W., M.S., Chief, Lewis Unitary Plan Activity & Chief, Engine Research Div., Lewis Flight Propulsion Lab., N.A.C.A. (Cleveland).

Weiss, Herbert A., M.S. in Ae.E., Ballistician & Deputy Chief, Terminal Ballistic Labs. & Chief, Weapons Effectiveness Branch, Ballistic Research Labs. (Aberdeen Proving Ground).

Elected to MEMBER Grade

Boatwright, Lewellyn T., Jr., M.S., Major, U.S.A.F.; Air Technical Liaison Officer, 7880th MID.

FitzSimmons, Richard D., B.S. in A.E., Engineering Designer, Boeing Airplane Co. (Seattle).

Foley, William R., S.B. in A.E., Supervisor, Power Plant Installation Design, Chance Vought Aircraft Div., United Aircraft Corp.

Hawks, Charles R., B.S., Lt. Colonel, U.S.A.F.; Deputy Chief, Los Angeles Engineering Field Office, Air Research & Development Command (Los Angeles).

Howard, William R., B.S. in M.E., Wind Tunnel Test Engineer, Aerodynamics Section, Wind Tunnel Group, Douglas Aircraft Co., Inc. (Santa Monica).

Marshall, Daniel Q., M.Sc. in I.E., Section Engineer, Aircraft Gas Turbines Sections, General Electric Co. (Lockland).

Martin, Charles C., Jr., M.S. in Aero., Missiles Adviser, Service Dept., Douglas Aircraft Co., Inc. (Santa Monica).

Ojea, Emilio A., Ing., Chief Engineer, Aerotax.

Peters, Jack D., B.Ae.E., Chief Engineer, Gordon D. Brown & Associates.

Pitt, Paul A., Chief Engineer, Development Div., Solar Aircraft Co.

Potts, Clarence, Senior Design Draftsman, A. V. Roe Canada Ltd.

Roach, Robert E., Jr., B.S., Structures Development Engineer, Chance Vought Aircraft Div., United Aircraft Corp. (Dallas).

Soprou, Alex F., B.E.Ae.E., Mechanical & Structural Engineer, McConathy, Hoffman & Assoc., Inc.

White, Alford W., B.S. in E.E., Commercial Engineer, General Electric Co.

Transferred to MEMBER Grade

Albert, Harry C., Major, U.S.A.F.; Technical Inspector, Inspector General's Dept., Hqs. Air Rescue Service (Washington, D.C.).

Barnes, Kenneth E., B.A., Airplane Specifications Engineer, Lockheed Aircraft Corp.

Beadling, John D., B.S. in Ae.E., Engineering Draftsman, Class III, Helicopter Div., Bell Aircraft Corp.

Parr, John M., B.S.E.

Rao, G. V. R., D.Sc. in Ae.E., Asst. Prof. of Aero. Engineering, Indian Institute of Science (India).

Elected to Associate Member Grade

Chorley, Percy E., General Sales Mgr., AVICA Equipment, Ltd.

Groder, Morris L., Radar & Communication Engineer, Bureau of Aeronautics, Dept. of the Navy.

Miccio, Joseph V., M.A., General Mgr., Electronics Div., Curtiss-Wright Corp. (Carlstadt, N.J.).

Siegel, Herman, Sales Engineer, Aviation Engineering Corp.

Elected to Technical Member Grade

Costello, Frank J., B.C.E., Stress Analyst, Republic Aviation Corp.

Foster, Leslie E., B.S.E.E., Jr. Engineer, Chance Vought Aircraft Div., United Aircraft Corp. (Dallas).

Ligh, J. Yen, Draftsman, Anderson, Greenwood & Co.

Morris, Maron L., B.S., Senior Test Engineer, Research Div., Wright Aero. Corp. Div., Curtiss-Wright Corp.

Ramsey, Joseph C., B.S. in Ae.E., Aerodynamics Engineer, Consolidated Vultee Aircraft Corp. (San Diego).

Schermerhorn, Ray E., B.S., Design Engineer, Hiller Helicopters.

Transferred to Technical Member Grade

Archambault, Roger G., B.A.E., Flight Test Analyst "A," Aerophysics Lab., North American Aviation, Inc.

Baker, Emmet E., Jr., Captain, U.S.A.F.; Asst. Chief, Communications Branch, Electronics Div., Hq., A.R.D.C. (Baltimore).

Barrett, Warren M., B.S. in Ae.E., Jr. Test Engineer, Pratt & Whitney Aircraft Div., United Aircraft Corp.

Beke, Andrew L., B.Ae.E., Aero. Research Intern, N.A.C.A. (Cleveland).

Bleviss, Zegmund O., Ph.D., Research Aerodynamicist, Douglas Aircraft Co., Inc. (Santa Monica).

Braddock, Donald E., B.Ae.E., Jr. Engineer, Power Plant Analysis Group, Chance Vought Aircraft Div., United Aircraft Corp.

Braue, John W., Jr., B.Ae.E., Jr. Test Engineer, Combustion Research Dept., Wright Aero. Corp. Div., Curtiss-Wright Corp.

Cardinal, Saviour, Jr., B.A.E., Engineer, Westinghouse Electric Corp. (S. Philadelphia).

Chaffee, James C., Engineering Draftsman "B," Anaheim Div., Northrop Aircraft, Inc.

Chiang, Shih-Fei, M.S., Student, University of California.

Chippendale, George R., M.S. in Ae.E., Control Systems Engineer, D.I.C. Staff, Massachusetts Institute of Technology.

Coburn, Robert S., B.S. in Ae.E., Flight Test Engineer, North American Aviation, Inc.

Cochran, Richard C., B.S. in Ae.E., Product Engineer, B.O.P. Assy. Div., General Motors Corp.

Cockburn, John, Jr., A.A., Engineering Asst.-Design Draftsman, Northrop Aircraft, Inc.

Compagnon, Michel A., B. of A.E., Student Trainee, Aviation Gas Turbine Div., Westinghouse Electric Corp.

Concha, Joseph I., M.S., General Aero. Engineer, Air Technical Analysis Center, Wright-Patterson Air Force Base.

Conine, Robert D., B.S.M.E., Graduate Student, Cornell University.

Cordani, Eugene J., B.Ae.E., Engineering-Draftsman, Helicopter Div., Bell Aircraft Corp.

Curren, Arthur N., B.S.M.E. (Aero.), Aero. Research Intern, N.A.C.A. (Cleveland).

Duffy, Robert E., B.S.Ae.E., Aero. Engineer, Aerodynamic Branch, Performance Unit, Wright-Patterson Air Force Base.

Dupaquier, Pierre, B.S., Engineering Draftsman, North American Aviation, Inc.

Dutko, Theodore, B.A.E., Weights Analyst, Weights Engineering Dept., North American Aviation, Inc. (Los Angeles).

Dwerlkotte, Joseph B., B.S. in M.E., Design Engineer, Boeing Airplane Co. (Wichita).

Eckert, Emery E.

English, Robert B., B.S. in Ae.E., 2nd Lt., U.S.A.F.

Erlandson, Charles E., Sr.

Firman, Roy S., B. of M.E. (Aero.), Aero. Engineer, Design Work—Guided Missiles, Bell Aircraft Corp.

Franks, Ralph W., M.S.Ae.E., Aero. Research Scientist, Full Scale & Flight Research Div., Ames Aero. Lab., N.A.C.A.

Frazer, Robert E., II, Draftsman, Engineering Dept., Eastern Air Lines (Miami).

Frozina, Casimir J., B. of Ae.E., Engineering Draftsman, Helicopter Div., Bell Aircraft Corp.

Gallagher, Robert E., B.S. in Ae.E., 2nd Lt., U.S.A.F., Weather Officer & Forecaster, 18th Weather Sq., M.A.T.S.

Gantt, Ben K., B.S., Design Engineer, Goodyear Aircraft Corp.

Gates, Talbert M., Captain & Pilot, U.S.A.F.; Research & Development Officer, 6556th Guided Missiles Sq., Patrick Air Force Base.

Geimer, Robert G., B.Ae.E., Research Engineer on Rocket Motors, Bell Aircraft Corp.

Grieco, Joseph P., B.Ae.E., Jr. Test Engineer, Experimental Testing & Engine Devel., Wright Aero. Corp. Div., Curtiss-Wright Corp.

Gruenberg, William B., B.S. in M.E. (Aero.), Stress Analyst "C," North American Aviation, Inc. (Downey).

Harris, Bentley H., Jr., B.A.E., Lt. Colonel & Senior Pilot, U.S.A.F.; Student Officer, New York University.

Hayos, Fred G., Jr., M.S. (Aero.), Associate Engineer, Research & Development on Rocket Thrust, Reaction Motors, Inc.

Herr, Frank M., B.S., Engineer's Aide, Aerodynamic Analysis-Study, Marquardt Aircraft Co.

Kanner, Martin, B. of A.E., Aero. Engineer, Simmonds Aerocessories, Inc.

Kendro, John J., B.Ae.E., Jr. Engineer, Air Frame Designer, Chance Vought Aircraft Div., United Aircraft Corp.

Kent, Harry S., B.S. in M.E., Design Engineer (Jr.), Chance Vought Aircraft Div., United Aircraft Corp.

Kochis, Thomas R., B.S. in A.E., Design Engineer, International Derrick & Equipment Co.

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Analysis of measurements of the boundary layer under zero-heat transfer conditions, at tunnel Mach Numbers of 1.73 to 2.25 and Reynolds Numbers of 4×10^6 to 20×10^6; measurements of skin friction and heat transfer for subsonic flow through a pipe.

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Calculations of the cooling required to stabilize the boundary layer using a Prandtl Number of 0.75 and the Sutherland viscosity-temperature law; comparison with Lees' results.

A Calculation Method for Three-Dimensional Laminar Boundary Layers. R. Timman. *Netherlands, Nationaal Luchtvaartlaboratorium, Amsterdam, Report No. F.66 (Reports and Transactions,* Vol. 16, 1951, pp. F31–F43), August 24, 1950. 13 pp., illus. 11 references.

Development of the equations for, and a method of solving, the three-dimensional boundary layer. The momentum equations for the three-dimensional potential flow about a body of arbitrary shape are expressed in curvilinear coordinates and are reduced to a set of quasilinear first-order differential equations by introducing two parameters that characterize the velocity profile. These equations are solved by the method of characteristics. The conditions at the stagnation point are taken as the initial values for use in the method of characteristics.

Skin-Friction and Heat-Transfer Characteristics of a Laminar Boundary Layer on a Cylinder in Axial Incompressible Flow. R. A. Seban and R. Bond. *Journal of the Aeronautical Sciences,* Vol. 18, No. 10, October, 1951, pp. 671–675, illus. 4 references.

Exact solution for laminar boundary layer of an incompressible fluid of constant properties on a slender circular cylinder with axis parallel to the flow. The skin-friction and heat-transfer coefficients are calculated for a fluid with a Prandtl Number of 0.715; results are compared with flat-plate theory.

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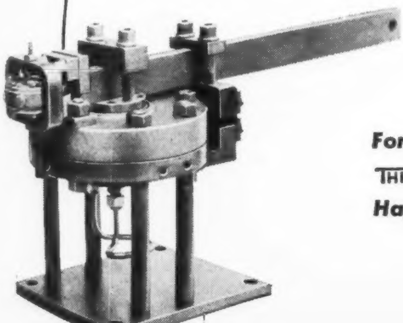

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Research program and facilities for studying hypersonic flow ($M > 5$). Details are given of the 12- by 12-cm. hyperballistic tunnel. The research program is mainly concerned with the physical problems of air condensation, Mach Number determination, effect of temperature on tunnel operation, boundary layers, and instrumentation. Some measurements of boundary layer and flow separation are reported.

Method of Determinining Initial Tangents of Contours of Flow Variables Behind a Curved, Axially Symmetric Shock Wave. George P. Wood and Paul B. Gooderum. *U.S., N.A.C.A., Technical Note No. 2411*, July, 1951. 44 pp., illus. 14 references.

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Development of an approximate method for obtaining the velocity potential for two-dimensional compressible flow. Using power series expansion, second-order approximations are determined. The method is demonstrated by determining the velocity potentials for a wave-shaped wall in free stream, in a closed tunnel, and in an open tunnel. The analysis is extended to obtain the solution for a body of arbitrary shape.

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Aerodynamic Methods Applied to Turbo-Machine Research. J. Lalive d'Epinay. *Brown Boveri Review*, Vol. 37, No. 10, October, 1950, pp. 357–367, illus. 9 references.

Test equipment at Brown, Boveri, and Co., Ltd., Switzerland, for studying axial flow turbomachines. Tests are carried out on stationary cascades of blades and on multistage blading. Observations were made on blade profiles and cascades for axial compressors in a supersonic wind tunnel and in a water canal. Schlieren apparatus, instrumentation, and the profile projector for studying blade shapes are considered.

Self-Induced Vibrations of Turbo-Machine Blades. Ch. Bellenot and L. Lalive d'Epinay. *Brown Boveri Review*, Vol. 37, No. 10, October, 1950, pp. 368–376, illus. 3 references.

Analysis of the phenomenon of self-induced vibration of blades having two degrees of freedom. The cause of the vibrations is established first and the mechanism by which the vibration takes place is explained. A method is developed for calculating the critical velocities at which bending or torsional vibration appears, considering both the steady and transient states.

Approximate Design Method for High-Solidity Blade Elements in Compressors and Turbines. John D. Stanitz. *U.S., N.A.C.A., Technical Note No. 2408*, July, 1951. 76 pp., illus. 13 references.

Development of an approximate method for compressible, nonviscous flow for blade elements with prescribed velocities along the profile. The method is based upon channel-type flow between blade elements. The first approximation is satisfactory for very-high solidity blades, such as in radial- and mixed-flow compressors; it assumes that across the channel between blade elements the velocity is constant and the flow direction is equal to that of the blade-element camber line. The second approximation, suitable for solidities in the range of present turbine nozzles, partially corrects for the velocity variation and the change in flow direction across the channel. Two numerical examples illustrate the method.

A Rapid Approximate Method for Determining Velocity Distribution on Impeller Blades of Centrifugal Compressors. John D. Stanitz and Vasily D. Prian. *U.S., N.A.C.A., Technical Note No. 2421*, July, 1951. 31 pp., illus. 11 references.

Development of an approximate analytic method for compressible and incompressible, nonviscous, two-dimensional flow. The velocities along the blade surfaces are obtained approximately, neglecting velocity variations across the channel between the blades. The method is applied to eight numerical examples for which relaxation solutions of the flow are known.

Theoretical and Experimental Investigations of Axial Flow Compressors. I, II. John T. Bowen, Rolf H. Sabersky, and W. Duncan Rannie. *California Institute of Technology, Mechanical Engineering Laboratory*, January, July, 1949. 275, 184 pp., illus. 46, 15 references.

I. Analysis of results of theoretical and experimental studies. A theory is developed for perfect fluid flow in axial turbomachines; data on a specially designed test compressor are compared with the theory. The testing equipment and procedure are described. Design methods are developed for increasing flow rate, based on various blading configurations. **II.** Measurements of two- and three-dimensional flow patterns in the test compressor; comparison with the design theory; location and extent of losses in an axial turbomachine; analysis of real fluid effects.

Influence of Wall Boundary Layer upon the Performance of an Axial-Flow Fan Rotor. Emanuel Boxer. *U.S., N.A.C.A., Research Memorandum No. L6J18b*, May 19, 1947. 20 pp., illus. 3 references.

Preliminary Study of Stability of Flow from Two Ducts Discharging into a Common Duct. Albert I. Bellin, D. Richard Messina, and Paul B. Richards. *U.S., N.A.C.A., Technical Note No. 2417*, July, 1951. 33 pp., illus. 3 references.

Theoretical and experimental investigation of the oscillations and asymmetries in the flow. A two-dimensional potential solution was studied to obtain the form of the ideal flow and to see if the theoretical solution is unique. This solution does not account for the oscillations and asymmetries in actual symmetric duct configurations. A qualitative analysis was carried out for the case of turbulent mixing between the two ducts and the fluid in the common duct. The problem was studied experimentally in a two-dimensional water table.

Heat Transfer to a Fluid Flowing Turbulently in a Smooth Pipe with Walls at Constant Temperature. R. A. Seban and T. T. Shimazaki. *American Society of Mechanical Engineers, Transactions*, Vol. 73, No. 6, August, 1951, pp. 803–807, Discussion, pp. 807–809, illus. 10 references.

Comparison of heat-transfer coefficients obtained under conditions of constant wall temperature and of linear variation of wall temperature. Heat-transfer coefficients were obtained by an iterative method that uses the results of Martinelli as a first approximation.

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THERMOAERODYNAMICS

Aerodynamic Heating at High Speeds. T. Nonweiler. *British Interplanetary Society, Journal*, Vol. 10, No. 4, July, 1951, pp. 160–176, illus. 5 references.

Calculation of the mean temperature of a plane surface on a missile that is moving steadily through the atmosphere at speeds of the order of the escape velocity and at an altitude where the boundary-layer flow is laminar and does not slip at the surface. The variation of temperature with time is neglected. Calculations of the mean surface temperature of a missile in the equilibrium condition were carried out for a circling orbit for various values of the surface angle to the direction of motion and for different wing loadings of the missile in level flight at the escape velocity.

Readers' Forum: Astroballistic Heat Transfer. R. N. Thomas and F. L. Whipple. *Journal of the Aeronautical Sciences*, Vol. 18, No. 9, September, 1951, pp. 636, 637. 2 references. Summary of work on heat transfer to rapidly moving objects; free-flight study of ablation.

WINGS & AIRFOILS

Some Flight Measurements of Pressure-Distribution and Boundary-Layer Characteristics in the Presence of Shock. John A. Zalovcik and Ernest P. Luke. *U.S., N.A.C.A., Research Memorandum No. L8C22*, July 23, 1948. 50 pp., illus. 4 references.

The Interaction of Boundary Layer and Compression Shock and Its Effect upon Airfoil Pressure Distributions. H. Julian Allen, Max. A. Heaslet, and Gerald E. Nitzberg. *U.S., N.A.C.A., Research Memorandum No. A7A02,* April 10, 1947. 26 pp., illus. 4 references.

A Summary Report on the Effects of Mach Number on the Span Load Distribution on Wings of Several Models. Henry Jessen, Jr. *U.S., N.A.C.A., Research Memorandum No. A7C28,* July 15, 1947. 21 pp., illus. 2 references.

Effects of Combinations of Aspect Ratio and Sweepback at High Subsonic Mach Numbers. Alfred A. Adler. *U.S., N.A.C.A., Research Memorandum No. L7C24,* June 4, 1947. 21 pp., illus. 4 references.

Aerodynamic Characteristics at Subcritical and Supercritical Mach Numbers of Two Airfoil Sections Having Sharp Leading Edges and Extreme Rearward Positions of Maximum Thickness. A. J. Eggers, Jr. *U.S., N.A.C.A., Research Memorandum No. A7C10,* November 6, 1947. 18 pp., illus. 6 references.

Tests at $M = 0.3$ to $M = 0.9$ on a 12 per cent-chord-thick, single-wedge airfoil section and a reversed N.A.C.A. 0012 section; comparison with the conventional N.A.C.A. 0012 section.

The Calculation of Drag for Airfoil Sections and Bodies of Revolution at Subcritical Speeds. Max. A. Heaslet and Gerald E. Nitzberg. *U.S., N.A.C.A., Research Memorandum No. A7B06,* April 23, 1947. 42 pp., illus. 24 references.

An Empirically Derived Method for Calculating Pressure Distributions over Airfoils At Supercritical Mach Numbers and Moderate Angles of Attack. Gerald E. Nitzberg and Loma E. Sluder. *U.S., N.A.C.A., Research Memorandum No. A7B07,* April 1, 1947. 45 pp., illus. 6 references.

The Lift Distribution on Low Aspect Ratio Wings at Subsonic Speeds. H. R. Lawrence. *Journal of the Aeronautical Sciences,* Vol. 18, No. 10, October, 1951, pp. 683–695, illus. 16 references. Review and clarification of existing low aspect ratio wing theory for rectangular plan forms; extension of the theory to more general plan forms; validity of the theory.

Effects of 45° Sweepback on the High-Speed Characteristics of a Wing Having a Modified NACA 16-012 Airfoil Section. Luke L. Liccini. *U.S., N.A.C.A., Research Memorandum No. L6K18a,* July 18, 1947. 17 pp., illus. 3 references.

A Simple Approximate Method for Obtaining Spanwise Lift Distributions over Swept Wings. Franklin W. Diederich. *U.S., N.A.C.A, Research Memorandum No. L7I07,* May 10, 1948. 12 pp., illus. 9 references.

Exploratory Wind-Tunnel Investigation of Wings and Bodies at $M = 6.9$. Charles H. McLellan. *Journal of the Aeronautical Sciences,* Vol. 18, No. 10, October, 1951, pp. 641–648, illus. 12 references. Results of tests in the Langley 11-in. hypersonic tunnel; description of apparatus, models, and instrumentation.

Interference Between Wing and Body at Supersonic Speeds—Theoretical and Experimental Determination of Pressures on the Body. R. H. Cramer. *Journal of the Aeronautical Sciences,* Vol. 18, No. 9, September, 1951, pp. 629–632, illus. 9 references.

Comparison of experimental data with values calculated from Ferrari's theory of wing-body interference for the induced pressure on an axially symmetric body, aft of a lifting wing, in supersonic flow.

Aerodynamic Characteristics Including Scale Effect of Several Wings and Bodies Alone and in Combination at a Mach Number of 1.53. Milton D. Van Dyke. *U.S., N.A.C.A., Research Memorandum No. A6K22,* December 20, 1946. 84 pp., illus. 12 references.

Effect of a Nacelle on the Low-Speed Aerodynamic Characteristics of a Swept-Back Wing. Frederick H. Hanson, Jr., and Robert E. Dannenberg. *U.S., N.A.C.A., Research Memorandum No. A8E12,* July 21, 1948. 71 pp., illus. 1 reference.

Wind-Tunnel Tests at Low Speed of Swept and Yawed Wings Having Various Plan Forms. Paul E. Purser and M. Leroy Spearman. *U.S., N.A.C.A., Research Memorandum No. L7D23,* May 22, 1947. 83 pp., illus. 15 references.

Tests on sweptback, sweptforward, and yawed wings in the Langley 7- by 10-ft. tunnel at air speeds of 80 and 60 m.p.h. and an effective Reynolds Number range of 9.92×10^5 to 2.0×10^6; comparison of test data with theoretical analyses.

Aeroelasticity

Flight Investigation of the Effect of Transient Wing Response on Wing Strains of a Twin-Engine Transport Airplane in Rough Air. Harry C. Mickleboro and C. C. Shufflebarger. *U.S., N.A.C.A., Technical Note No. 2424,* July, 1951. 21 pp., illus. 4 references.

Acceleration and strain measurements were made at a number of spanwise stations on a twin-engined transport in clear-air turbulence at different wing fuel loads and two speed conditions at altitudes between 3,000 and 4,000 ft.

Further Application of the Electronic Differential Analyzer to the Oscillation of Beams. Carl E. Howe. **Appendix I—Closed-Loop Continuous Drift Compensation.** L. L. Rauch. **Appendix II—Modification of the Brush DC Amplifier BL-913 for Use with an Electronic Differential Analyzer.** L. L. Rauch and R. H. Dougherty. *Michigan, University, Aeronautical Research Center, External Memorandum No. UMM-47,* June 1, 1950. 54 pp., illus. 2 references.

Solution, using an electronic differential analyzer, of the problem of determining the normal modes of oscillation of a uniform free-free beam, using as end conditions the equations to zero, at both ends, of the expressions for bending moment and shearing force. This solution considers the effects of shearing force and rotary inertia. This is an extension of the research reported in UMM-28.

Application of the Electronic Differential Analyzer to the Oscillations of Beams, Including Shear and Rotary Inertia. C. E. Howe, R. M. Howe, and L. L. Rauch. *Michigan, University, Aeronautical Research Center, Memorandum No. UMM-67,* January, 1951. 98 pp., illus., folding charts. 13 references.

Solution of a fourth-order differential equation subject to boundary conditions imposed by restraints, or lack of them, on the end of a beam. Theoretical analysis of the vibrating beam and the formulation of equations that can be solved by the computer; use of the analyzer for obtaining solutions for uniform and nonuniform beams. Tables and curves show the results obtained for the vibrations of uniform free-free beams. This work is a continuation of UMM-47.

Shear Centre, Flexural Centre, and Flexural Axis. R. Tatham. *Aircraft Engineering,* Vol. 23, No. 269, July, 1951, pp. 209–210, illus. Definition of terms for unswept wings; modifications needed to explain accurately the terms for sweptback wings.

Torsional Column Strength of Thin-Walled Open Sections. I. M. K. Malik. *Aircraft Engineering,* Vol. 23, No. 269, July, 1951, p. 211, illus. 4 references. A mechanical method of calculating the torsional bending constant for a rolled Z-section stringer.

Readers' Forum: Comment on "Vibration of Rectangular Plates" by Harold Lurie. Charles Massonnet. **Author's Reply.** *Journal of the Aeronautical Sciences,* Vol. 18, No. 10, October, 1951, p. 703.

Air Transportation (41)

Some Aspects on the Ground Time Factor in Aircraft Utilization. Bertil Björkman. *Saab Sonics,* No. 14, April–June, 1951, pp. 14, 18, 24, 25. Maintenance, ground handling of passengers and cargo, and official paper work that cause delays and loss of optimum aircraft utilization.

Soviet Transport Aviation. *Aviation Age,* Vol. 16, No. 1, July, 1951, pp. 46, 47, illus., map.

Airplane Design (10)

AIRPLANE DESCRIPTIONS

Red Air Inventory—Bombers. *Aviation Age,* Vol. 16, No. 1, July, 1951, pp. 43–45, illus. Photographs and specifications; data on strategic bombing setup and equipment.

Red Air Inventory—Fighters. *Aviation Age,* Vol. 16, No. 1, July, 1951, pp. 40–42, illus. Photographs and specifications; development trends.

Red Air Inventory—Transports, Trainers, Miscellaneous. *Aviation Age,* Vol. 16, No. 1, July, 1951, pp. 48, 49, illus. Photographs and specifications.

Breguet 960 Vultur Turboprop/Turbojet Fighter, France. *Les Ailes,* Vol. 31, No. 1.329, July 21, 1951, pp. 8, 9, illus. In French.

Fokker S.14 Single-Engined Turbojet Transition Trainer, Netherlands. *Aviation Week,* Vol. 55, No. 5, July 30, 1951, pp. 29, 30, 33, illus., cutaway drawings. *The Aeroplane,* Vol. 81, No. 2087, July 20, 1951, pp. 69–71, illus., cutaway drawing.

Allison Turbo-Prop Engines Power 3 New Cargo Planes—

★ **The Lockheed XC-130**

★ **The Douglas R6D**

★ **The Lockheed R7O**

While testing continues with the first U.S. Turbine Transport—the Allison Turbo-Liner, built by Convair—military contracts have been awarded for the installation of Allison Turbo-Prop engines in three additional types of transport aircraft.

★ The Lockheed XC-130 — a U.S.A.F. four-engine medium cargo plane—is *the first military transport ever designed originally around Turbo-Prop power*. It won U.S.A.F. design competition over five other makes and the selection of Allison engines represents another *first* for Allison in the development of turbine transports in this country.

★ The new Navy-sponsored R6D is a modified configuration of the world-famous Douglas DC6A Liftmaster.

★ The Navy R7O is the new turbine version of the Lockheed Super Constellation.

Allison Turbo-Prop engines were selected for all three aircraft because they develop more power with less than half the weight of present engines in this power class.

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Builders of J35 Axial, J33 Centrifugal Flow Turbo-Jet Engines and T40 Turbo-Prop Engines

Proof-testing engines today for the airplanes of tomorrow.

Martin B-57A Twin-Engined Turbojet Night-Intruder Bomber. *Aviation Week*, Vol. 55, No. 4, July 23, 1951, pp. 19, 20, 22–24, 27, 28, 31, illus. Production plans for the B-57A, a U.S. version of the English Electric Co. Ltd. Canberra, at The Glenn L. Martin Co.

Short Sealand 8-Place Twin-Engined Amphibian, England. *The Aeroplane*, Vol. 80, No. 2083, June 22, 1951, pp. 784–786, illus.

Tu-10 Twin-Engined Turbojet Bomber, U.S.S.R. *Aviation Age*, Vol. 16, No. 1, July, 1951, pp. 38, 39, illus., cutaway drawing.

WING GROUP

SAAB Aircraft Wing Structures. Olle Ljungström. *Saab Sonics*, No. 14, April–June, 1951, pp. 4–11, 24, illus. 1 reference. Study of the structural details of wings on Saab's all-metal monoplanes (aircraft gross weights range from 2,000 to 35,000 lbs.). Planes considered are the Saab B-5 (Northrop 8A-1), -17, -18B, -21A, -24, -29, the Scandia, and the Safir. Wing weights are compared in order to determine wing design efficiency.

Airports & Airways (39)

Analysis of a Fixed-Block Terminal Area, Air Traffic Control System. S. M. Berkowitz. *Franklin Institute, Laboratories for Research and Development, Final Report No. F-2164-2*, May 1, 1951. 87 pp., illus., folding charts. 1 reference.

Analysis, using a graphic simulator developed at the Franklin Institute Laboratories, of a practical fixed-block system, considering all aircraft landing during one 24-hour period and a traffic situation comparable to that at a major airport. The results of the fixed-block analysis are compared with those of an ideal system that presupposes perfect knowledge and perfect execution of an optimum system.

Regularization of Air Traffic. I—A Study of Flight Time Estimate Errors. Dimitry E. Olshevsky. *Cornell Aeronautical Laboratory, Inc., Report No. JA-693-P-1*, June 7, 1951. 40 pp., illus., folding charts. 3 references.

An analytic study, a statistical investigation of flight-time estimate errors, and a discussion of operational expedients for their alleviation derived from this study. Expressions for the estimated flight-time error were derived on the basis of known errors of basic flight components.

Regularization of Air Traffic. II—Systems Organization of Air Traffic. Dimitry E. Olshevsky. *Cornell Aeronautical Laboratory, Inc., Report No. JA-693-P-2*, May 14, 1951. 12 pp., illus., folding chart. 3 references.

Systems engineering analysis of the organization, necessity, and scope of all-weather air-traffic control based on air-traffic coordination and guidance. The role of Terminal Service Coordinating Equipment (TSCE) in the system is studied.

Regularization of Air Traffic. III—Problems of Alternate Airports and Rerouting Operations. Dimitry E. Olshevsky. *Cornell Aeronautical Laboratory, Inc., Report No. JA-693-P-3*, June 7, 1951. 50 pp., illus., folding charts. 2 references.

Theory of the cross correlation of terminal capacities in alternates; statistical applications of the analysis to the evaluation of alternates; rerouting operations in frontal closures. The Buffalo-Rochester (N.Y.) airports provide the data for this analysis.

Regularization of Air Traffic. IV—Optimum Sequencing of Weather Forecasts. Dimitry E. Olshevsky. *Cornell Aeronautical Laboratory, Inc., Report No. JA-693-P-4*, June 25, 1951. 20 pp., illus., folding charts. 2 references.

Development of a theory of optimum spacing of weather forecasts considering only the aeronautical forecasts of the Weather Bureau. The theory is based on establishing a criterion of forecasting efficiency—the ratio of benefits derived to costs incurred.

Regularization of Air Traffic. V—Suggestions for the Improvement of Forecasting for Air Traffic Control. Dimitry E. Olshevsky. *Cornell Aeronautical Laboratory, Inc., Report No. JA-693-P-5*, June 22, 1951. 16 pp., illus. 1 reference.

Isochronal methods of presentation of forecasts; organization changes that will improve forecasting for air-traffic control; local fine-mesh forecasting systems; air-borne weather reporting stations.

Regularization of Air Traffic. VI—Research and Consultation Notes. Dimitry E. Olshevsky. *Cornell Aeronautical Laboratory, Inc., Report No. HA-693-P-6*, May 14, 1951. 28 pp., illus. 7 references. Merits of compulsory versus advisory traffic coordination; a mathematical theory of the internal saturation of terminals.

Pressure Fueling. *Shell Aviation News*, No. 156, June, 1951, p. 24, illus. Operation and uses of the Shell Pressure Control Valve.

30-Degree Modified Slope-Line Approach-Light System. Roy E. Warren and H. J. Cory Pearson. *U.S., Civil Aeronautics Administration, Technical Development Report No. 137*, February, 1951. 7 pp., illus. 1 reference.

Aviation Medicine (19)

Tests Show Airsickness Can Be Stopped. *American Aviation*, Vol. 15, No. 10, August, 1951, pp. 26, 27, illus. Results of a three-month survey by Capital and United Air Lines of the use of dramamine as a prophylactic and therapeutic agent in treating airsickness cases.

Aircraft Oxygen Equipment Engineering Manual. *Ohio Chemical & Surgical Equipment Company*, 1951. 43 pp., illus.

Masks and accessories; outlet valves and plug-in connections; regulators and flow gages; cylinders, connections, and pressure gages; portable equipment; miscellaneous equipment; and recommended practices and typical installations.

Comfortization (23)

Air-Conditioning for Aircraft Cabins. R. Tourret and E. F. Winter. *Aircraft Engineering*, Vol. 23, No. 269, July, 1951, pp. 188–195, illus. 16 references.

I.C.A.N. standards of atmospheric conditions at altitude; aircraft cabin requirements for civil and military operations; installations for providing an air supply. Charts show the operating characteristics of various types of blowers and of four types of air-conditioning systems.

Air Conditioning in an American Fighter. C. A. H. Pollitt. *The Aeroplane*, Vol. 81, No. 2085, July 6, 1951, p. 15, illus.

Design and operation of the Hamilton Standard air-conditioning unit for jet fighter cockpits. The unit consists of a heat exchanger, a turbine that rotates at 60,000 r.p.m., $1^1/_2$-in. diameter aluminum tubing, and a thermostatically controlled mixing valve; total weight is 20 lbs.

A Preliminary Study of Ram-Actuated Cooling Systems for Supersonic Aircraft. Jackson R. Stalder and Kenneth R. Wadleigh. *U.S., N.A.C.A., Research Memorandum No. A7C04*, April 29, 1947. 36 pp., illus. 3 references.

Education & Training (38)

Military Air Training. *Aviation Age*, Vol. 16, No. 1, July, 1951, pp. 55–57, illus. Air Force training and flying clubs in the U.S.S.R.

Electronics (3)

Pilotless Aircraft Research. Welman A. Shrader. *Aeronautical Engineering Review*, Vol. 10, No. 10, October, 1951, pp. 24–29, illus.

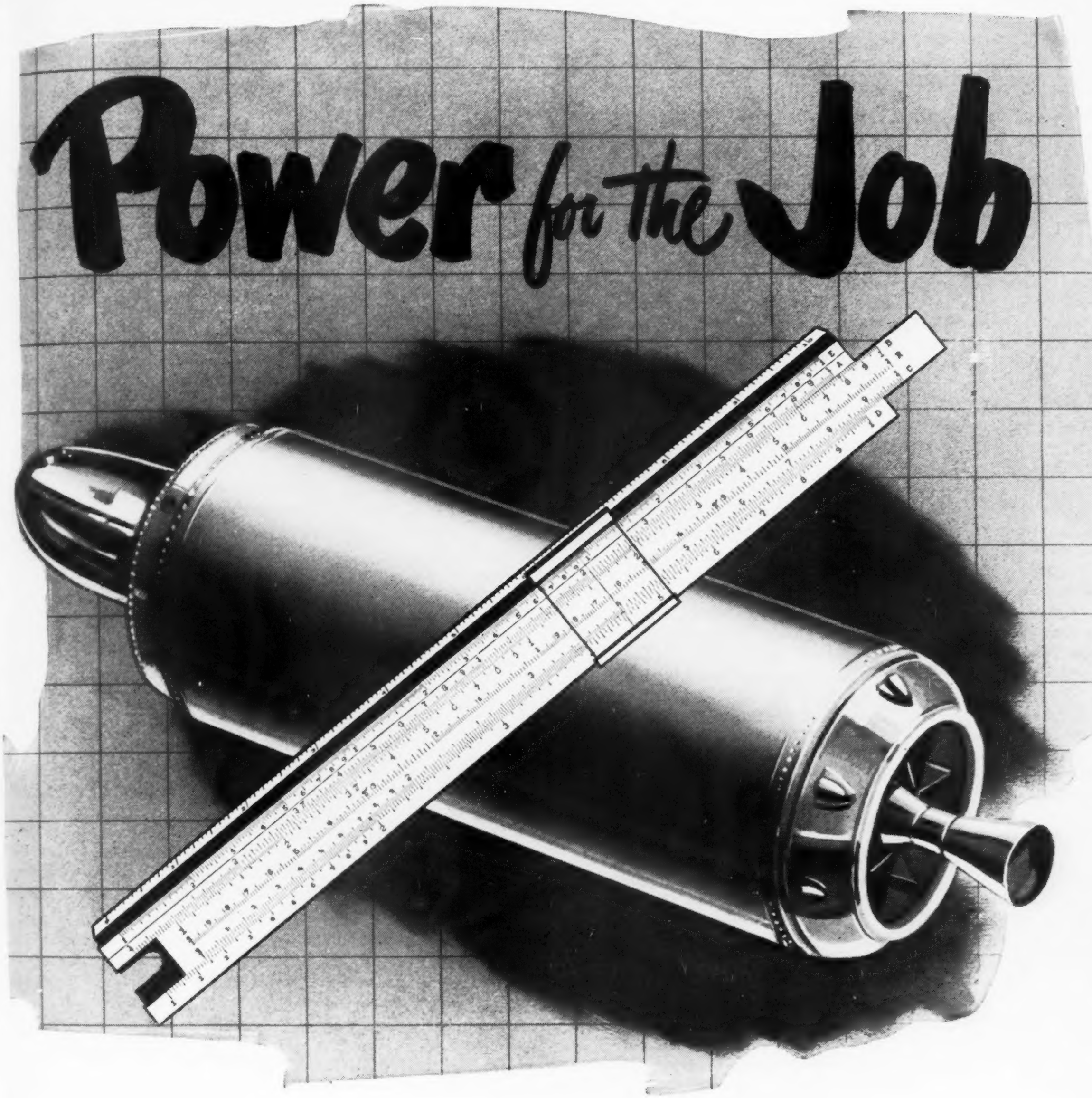
A report on N.A.C.A.'s research station at Wallops Island, Va. Data are obtained on transonic and supersonic flow conditions, using rocket-launched free-flying models. Electronic equipment used in controlling the model and receiving and recording the test data are discussed.

Defense Department Plans for Basic Research. Harold A. Zahl, E. R. Piore, and J. W. Marchetti. *Electronics*, Vol. 24, No. 8, August, 1951, pp. 82–87, illus.

Prospects for the continuance of basic electronics research; military contracts; man power policies of the Army, Navy, and Air Force; research facilities; coordination of research efforts by the Dept. of Defense.

Avionic Advances Revealed by Honeywell. David A. Anderton. *Aviotion Week*, Vol. 55, No. 5, July 30, 1951, pp. 21, 22, 25, illus.

Electronic devices presently built and developed by Minneapolis-Honeywell Regulator Co.: an accessory to the E-L autopilot which permits the pilot to maneuver the plane when the autopilot is engaged; a capacitance fuel gage; a center-of-gravity control that considers the effects of expended fuel and ammuni-


Power for the Job

tion on c.g. location; an altitude controller; a portable, eight-channel flight recorder; and cockpit control systems.

CIRCUITS & CIRCUIT ELEMENTS

Step Multiplier in Guided Missile Computer. Edwin A. Goldberg. *Electronics*, Vol. 24, No. 8, August, 1951, pp. 120–124, illus. 1 reference.

The Project Typhoon 4,000-tube analog computer used in the design of complete missile systems simulates missile and target characteristics. The high-precision step-multiplier is used to maintain orthogonality of the earth and missile axes systems during the computation process. It consists of an eleven-stage reversible binary counter and relay-driven variable-conductance networks. Each conductance network can be adjusted to the calculated value within ±0.001 per cent of full-scale conductance; the relays require about 100μ sec. to close or open. Diagrams show the circuits of the first two stages of the binary counter, the blocking oscillator, and the relay drive amplifier.

Investigation of the Utility of an Electronic Analog Computer in Engineering Problems. D. W. Hagelberger, C. E. Howe, and R. M. Howe. *Michigan, University, Aeronautical Research Center, External Memorandum No. UMM-28*, April 1, 1949. 213 pp., illus. 19 references.

Study of the applicability of the computer to applied research. The use of operational amplifiers in analog computers is explained; diagrams show the amplifier circuits as set up for handling various types of problems. Circuits and analyses are also presented for the components of the computer system.

Further Application of the Electronic Differential Analyzer to the Oscillation of Beams. Carl E. Howe. **Appendix I—Closed Loop Continuous Drift Compensation.** L. L. Rauch. **Appendix II—Modification of the Brush DC Amplifier BL-913 for Use with an Electronic Differential Analyzer.** L. L. Rauch and R. H. Dougherty. *Michigan, University, Aeronautical Research Center, External Memorandum No. UMM-47*, June 1, 1950. 54 pp., illus. 2 references.

Solution, using an electronic differential analyzer, of the problem of determining the normal modes of oscillation of a uniform free-free beam, using as end conditions the equations to zero, at both ends, of the expressions for bending moment and shearing force. This solution considers the effects of shearing force and rotary inertia. This is an extension of the research reported in UMM-28. Diagrams show the computer circuits for the solution of the problem. The Appendixes describe modifications in the computing and recording equipment.

Application of the Electronic Differential Analyzer to the Oscillation of Beams, Including Shear and Rotary Inertia. C. E. Howe, R. M. Howe, and L. L. Rauch. *Michigan, University, Aeronautical Research Center, Memorandum No. UMM-67*, January, 1951. 98 pp., illus., folding charts. 13 references.

Solution of a fourth-order differential equation subject to boundary conditions imposed by restraints, or lack of them, on the ends of a beam. The procedure for setting up equations suitable for computer solution and computer experimental techniques are explained. Diagrams show the circuits of the computer components. Design details and circuits are given for the drift-stabilizer d.c. amplifier and the computer power supply. This work is a continuation of UMM-47.

A New Analog Computer. S. Bosworth. *Electronics*, Vol. 24, No. 8, August, 1951, pp. 216, 218, 220, 222, 224, illus.

Design and operation of the Computer Corp. of America's Integro-Differential Analyzer (IDA), a desk-sized, inexpensive computer that is capable of solving eighth-order differential equations. The computer comprises 20 d.c. computing amplifiers, 23 precision ten-turn potentiometers, 8 integrating capacitors, a control panel, power supply, and setup board for wiring in the analog. Solutions appear graphically on a magnetic oscillograph.

High-Speed Sampling Techniques. B. R. Shepard. *Electronics*, Vol. 24, No. 8, August, 1591, pp. 112–115, illus. 1 reference. High-speed scanning systems for low-level operation; brief survey of the circuits and applicability of the multiple-element radial-beam scanner and f-m scanner.

An Introduction to Computer Concepts. I. John D. Goodell. *Radio & Television News*, Vol. 46, No. 2, August, 1951, *Radio-Electronic Engineering*, pp. 3–5, 30, illus. Basic principles; future potentialities.

Self-Balancing Strain Gauge Equipment. Alvin B. Kaufman. *Radio & Television News*, Vol. 46, No. 2, August, 1951, *Radio-Electronic Engineering*, pp. 12–14, illus. 2 references. Design techniques, equipment, and circuits of balancing-type electronic recorders for strain-gage-indicated stresses.

Stress-Strain Recorder. *Electronics*, Vol. 24, No. 8, August, 1951, pp. 244, 246, illus.

An electronic recorder that automatically records stress-strain or load-deflection characteristics of aircraft armament equipment mechanisms. It consists of a measuring head and a recorder and is sensitive to deflections from 0.001 in. to 10 in.

Variable-Frequency Clock-Pulse Generator. Robert R. Rathbone. *Radio & Television News*, Vol. 46, No. 2, August, 1951, *Radio-Electronic Engineering*, pp. 19, 20, illus.

The variable-frequency clock-pulse generator developed at the M.I.T. Servomechanisms Laboratory provides positive 0.1-sec. half-sine-wave pulses at a 93-ohm impedance level, with pulse-repetition frequencies variable from 0.2 to 4.9 megacycles. Operation and components are discussed.

Methods of Developing Sweep and Marker Generator Signals. Cyril H. Brown. *Radio & Television News*, Vol. 46, No. 2, August, 1951, pp. 48, 49, 91, illus.

Precision Frequency Generators Using Single-Sideband Suppressed-Carrier Modulators. H. R. Holloway and H. C. Harris. *Sylvania Technologist*, Vol. 4, No. 3, July, 1951, pp. 64–67, illus.

Wide Range Logarithmic Amplifier. Claude H. Child. *Radio & Television News*, Vol. 46, No. 2, August, 1951, *Radio-Electronic Engineering*, pp. 6, 7, illus. 3 references. Input range is 100 db. below the maximum input of 5 volts.

A Servo Drive for Heterodyne Oscillators. Thaddeus Slonczewski. *Electrical Engineering*, Vol. 70, No. 8, August, 1951, p. 683, illus.

Study of Harmonic Power Generation. P. E. Russell and H. A. Peterson. *Electrical Engineering*, Vol. 70, No. 8, August, 1951, p. 690, illus. Analysis of the operation of a nonlinear static-element circuit that is used as a third harmonic generator. A differential analyzer is used to study the circuit.

D-C Amplifier with Reduced Zero-Offset. Will McAdam, R. E. Tarpley, and A. J. Williams, Jr. *Electronics*, Vol. 24, No. 8, August, 1951, pp. 128–132, illus. 7 references.

Input required to bring output to zero is less than 1.6 times peak-to-peak thermal fluctuations in new contact-modulated d.c. amplifier, corresponding to zero-offset of 10^{-12} ampere on current ranges and 1 microvolt on 20,000-megohm-per-volt voltage ranges.

New Unit Instruments. *General Radio Experimenter*, Vol. 26, No. 2, July, 1951, pp. 1–5, illus. Type 1203-A unit power supply, Type 1204-B unit variable power supply, and Type 1214-A unit oscillator (400 and 1,000 cycles).

Calculations for Class "C" Amplifiers with a Reactive Load. Desmond W. Cawood. *Sylvania Technologist*, Vol. 4, No. 3, July, 1951, pp. 56–59, illus. 1 reference.

Note on the Variations of Phase Velocity in Continuously-Wound Delay Lines at High Frequencies. I. A. D. Lewis. (*I.E.E., Radio Section, Paper No. 1160.*) *Institution of Electrical Engineers, Proceedings, Part III, Radio and Communication Engineering*, Vol. 98, No. 54, July, 1951, pp. 312–314, illus. 3 references.

Bridge-Tee Phase Modulators. *Radio & Television News*, Vol. 46, No. 2, August, 1951, *Radio-Electronic Engineering*, p. 8, illus.

Bridged-tee phase modulator circuits for low-level applications in which the relatively high attenuation does not incur a power loss. Wide-range phase shift with constant attenuation is obtained by varying a single control impedance.

COMMUNICATIONS

Round-the-World Voice Radio System. W. Waldo Lynch. *Radio & Television News*, Vol. 46, No. 2, August, 1951, pp. 36, 37, 106, 107, illus., map. Equipment and operation of P.A.A.'s Round-the-World Voice Radio System, which provides direct communication between the pilot of an aircraft and the ground station.

COMPONENTS

Harmonic Generation in the U-H-F Region by Means of Germanium Crystal Diodes. Frank D. Lewis. *General Radio Experimenter*, Vol. 26, No. 2, July, 1951, pp. 6–8, illus.

Germanium Diode Experience in SEAC Program. *U.S., National Bureau of Standards, Technical Report No. 1571,* July, 1951. 6 pp. 2 references.

A Visual Transistor Test Method and Its Application to Collector Forming. Rowland W. Haegele. (*Institute of Radio Engineers, Annual Conference on Electron Tubes and Solid State Devices,* Durham, N.H., June 22, 1951.) *Sylvania Technologist,* Vol. 4, No. 3, July, 1951, pp. 61–63, illus. 1 reference.

Tiny Transistor. *Aviation Week,* Vol. 55, No. 5, July 30, 1951, p. 26, illus.

A junction transistor, developed at Bell Telephone Laboratories, consists of a rod-shaped piece of germanium, treated to form a thin electrically positive layer between two electrically negative layers. Encased in plastic, the transistor volume is about $^1/_{400}$ cu.in. The transistor draws only 0.6 microwatts power.

A High-Speed Crystal Clutch. *U.S., National Bureau of Standards, Technical Report No. 1553,* July, 1951. 4 pp.

The Measurement of Permittivity and Power Factor of Dielectrics at Frequencies from 300 to 600 Mc/s. J. V. L. Parry. (*I.E.E., Measurements Section, Paper No. 1158.*) *Institution of Electrical Engineers, Proceedings, Part III, Radio and Communication Engineering,* Vol. 98, No. 54, July, 1951, pp. 303–311, illus. 5 references.

Some Results on the Electrical Breakdown of Liquids Using Pulse Techniques. W. D. Edwards. *Canadian Journal of Physics,* Vol. 29, No. 4, July, 1951, pp. 310–324, illus. 8 references.

CONSTRUCTION TECHNIQUES

Small Continuous Furnace for Firing Printed Circuits. *U.S., National Bureau of Standards, Technical Report No. 1551,* July, 1951. 3 pp.

ELECTRON TUBES

New Cathode Design Improves Tube Reliability. D. R. Hill. *Electronics,* Vol. 24, No. 8, August, 1951, pp. 104–106, illus. 3 references. Structure contains reservoir of barium-strontium-carbonate emitting material.

Radio Valve Life Testing. R. Brewer. (*I.E.E., Radio Section, Paper No. 1021.*) *Institution of Electrical Engineers, Proceedings, Part III, Radio and Communication Engineering,* Vol. 98, No. 54, July, 1951, pp. 269–274, Discussion, pp. 274–277, illus. 15 references.

Electron Tube Curve Tracer. J. H. Kuykendall. *Radio & Television News,* Vol. 46, No. 2, August, 1951, *Radio-Electronic Engineering,* pp. 9–11, 29, illus.

Development at Tung-Sol Lamp Works, Inc., of a characteristic curve tracer that presents plate characteristic and transfer curves on a cathode-ray tube, showing a voltage or current calibration spot at the same time.

MEASUREMENTS & TESTING

Measuring Power Factor of Low-Loss Dielectrics. J. L. Dalke and R. C. Powell. *Electronics,* Vol. 24, No. 8, August, 1951, pp. 224, 226, 228, 230, 232, illus. 1 reference.

Design of a regenerative circuit for dielectric measurements. The circuit, which provides accurate measurements up to 300 megacycles, consists of a conventional coil, micrometer electrode system shunted by a voltmeter and a negative resistance in series.

NAVIGATION AIDS

Mountain-Top VOR Site Flight Tests. Thomas S. Wonnell. *U.S., Civil Aeronautics Administration, Technical Development Report No. 139,* March, 1951. 13 pp., illus. Installations in Idaho and California; results of flight tests.

POWER SUPPLIES

General Theory of Voltage Stabilizers. J. J. Gilvarry and D. F. Rutland. *Review of Scientific Instruments,* Vol. 22, No. 7, July, 1951, pp. 464–468, illus. 7 references.

Zero-Impedance Power Supply Termination. Jordan J. Baruch. *Electronics,* Vol. 24, No. 8, August, 1951, pp. 240, 242, 244, illus.

Wide-Range Voltage Regulators. Joseph Houle. *Electronics,* Vol. 24, No. 8, August, 1951, pp. 202, 204, 206, 208, 210, illus. 1 reference. Methods of obtaining a regulated power supply in which the voltage can be adjusted from several hundred volts down to zero; associated equipment.

SATURABLE REACTORS

Steady-State Analysis of Magnetic Amplifiers. W. H. Esselman. *Electrical Engineering,* Vol. 70, No. 8, August, 1951, p. 672, illus.

TELEMETRY

Converter Circuit for Phase-Shift Telemetering. F. G. Willey. *Electronics,* Vol. 24, No. 8, August, 1951, pp. 140, 212, 214, 216, illus. Design of a simple converter circuit for converting three-wire synchro data to a single phase-shifted signal for telemetering equipment.

TRANSMISSION LINES

Matching-Stub Calculations. Seizo Yamasita. *Radio & Television News,* Vol. 46, No. 2, August, 1951, *Radio-Electronic Engineering,* p. 32, illus. A nomograph for determining the position and length of matching stubs on Lecher wire lines.

WAVE PROPAGATION

A Phase-Comparison Method of Measuring the Direction of Arrival of Ionospheric Radio Waves. W. Ross, E. N. Bramley, and G. E. Ashwell. (*I.E.E., Radio Section, Paper No. 1134.*) *Institution of Electrical Engineers, Proceedings, Part III, Radio and Communication Engineering,* Vol. 98, No. 54, July, 1951, pp. 294–302, illus. 9 references.

Field-Power Conversion. Robert E. Perry. *Electronics,* Vol. 24, No. 8, August, 1951, p. 134, illus. Direct-reading conversion chart.

Equipment

ELECTRIC (16)

Progress Towards Electrical Serviceability. R. H. Woodall and V. A. Higgs. *Royal Aeronautical Society, Journal,* Vol. 55, No. 487, July, 1951, pp. 395–412, Discussion, pp. 413–423, illus.

Problems in the design of electric equipment for aircraft imposed by weight, size, climate, vibration, and safety considerations, from the point of view of increasing the time between maintenance periods and reducing maintenance work; design trends toward the solving of these problems.

Rotary Inverter Completely Shock Mounted. *Product Engineering,* Vol. 22, No. 8, August, 1951, pp. 128, 129, illus.

Four rubber shock mounts supported on aluminum legs isolate airplane vibrations from a 58-lb. aircraft rotary inverter. Inverter input is 26–29 volts d.c.; output is 2,500 volt-amperes. A cutaway drawing and a schematic circuit diagram show the components.

HYDRAULIC & PNEUMATIC (20)

Progress Towards Hydraulic Serviceability. R. H. Bound and H. G. Conway. *Royal Aeronautical Society, Journal,* Vol. 55, No. 487, July, 1951, pp. 424–439, Discussion, pp. 439–449, illus.

Critical evaluation of aircraft hydraulic systems and factors affecting performance; types of unserviceability that occur; design improvements and development techniques; installation and maintenance; control problems.

An Investigation of Hydraulic Damping. J. E. Campbell. *SAE Quarterly Transactions,* Vol. 5, No. 3, July, 1951, pp. 418–428, illus. 1 reference.

Investigation of the hydraulic damping or resistance properties of basic system components on an aircraft power-boost system. A detailed analysis is carried out of a control-surface power-boost system using the method of converting the mechanical-hydraulic system into its equivalent electric system.

Viscosity Conversion Charts. Nils M. Sverdrup. *Product Engineering,* Vol. 22, No. 8, August, 1951, pp. 179, 181, illus. Absolute and kinematic viscosity conversion charts.

H2. *R. M. Hollingshead Corp., Bulletin,* 1951. 16 pp., illus., fold. charts. History and development, properties, composition, test evaluation, and uses of H2, a noninflammable hydraulic fluid for aircraft.

Flight Operating Problems (31)

ICE PREVENTION & REMOVAL

Icing of "Low-Drag" Wing Sections. II. S. Lal. *Aeronautical Society of India, Journal*, Vol. 3, No. 2, May, 1951, pp. 32–46, illus. 8 references. Calculations of the performance conditions of an N.A.C.A. 662-series airfoil under icing conditions, with determination of the trajectories of the ice droplets.

Wind Tunnel Tests on the Effect of Accretion of Ice on Control Characteristics in Two-Dimensional Flow. A. S. Halliday, A. S. Batson, and D. K. Cox. *Gt. Brit., Aeronautical Research Council, Current Papers No. 42*, 1951 (May, 1950). 18 pp., illus. 3 references. British Information Services, New York. $0.65. Analysis of the influence of the trailing-edge angle of elevators and flaps on the adverse effects of ice accretion on control-surface performance.

Further Wind Tunnel Tests on the Effects of Ice Accretion on Control Characteristics. A. Spence. *Gt. Brit., Aeronautical Research Council, Current Papers No. 43*, 1951 (May, 1950). 12 pp., illus. 3 references. British Information Services, New York. $0.40.

Results of measurements on the effect of simulated ice accretion on control hinge moments, with varying trailing edge angles of the tail surface; comparison with previous tests.

Flight Safety & Rescue (15)

The Transportation of Dangerous Cargo by Air in the United States of America. Harris F. Reeve. *Transport and Communications Review*, Vol. 4, No. 1, January–March, 1951, pp. 50–56, illus.

Safety aspects of the carriage, either as freight or as passenger baggage, of dangerous material; review of Civil Air Regulations that outline the requirements for packing and marking such cargo, along with some of the regulations of the air carriers; outline of I.C.C. regulations pertaining to outage and to the labeling of dangerous shipments; explanation of labeling colors.

Crashworthiness. Horace Smith. *The Technical Instructor*, Vol. 6, No. 6, June, 1951, pp. 3–6.

An analysis of what has been done and what should be done to ensure passenger and crew survival in the event of an airplane crash, with emphasis on present fire hazards.

How to Prevent Fuel Tank Explosions. *American Aviation*, Vol. 15, No. 10, August 6, 1951, p. 22, illus.

The Graviner Explosion Suppression System detects an explosion in its earliest stages and discharges a suppressant that prevents generation of high temperatures and pressures. The system, now under test by Simmonds Aerocessories, Inc., suppresses the explosion without structural or heat damage.

Flight Testing (13)

A Recording System for Flight Test Data. P. A. Hufton, F. G. R. Cook, and P. S. Saunders. *Gt. Brit., Aeronautical Research Council, Current Papers No. 44*, 1951 (December 20, 1949). 13 pp., illus., folding chart. 2 references. British Information Services, New York. $0.50.

Analysis of the difficulties encountered in reading flight-test data from film recordings; form of record and recording apparatus. A system is proposed in which the data are recorded in the binary digital system and transcribed (on the ground) in either tabular or punched-tape form.

A Note on the Use of Time Series in the Analysis of Flight Test Series. W. P. Jones. *Gt. Brit., Aeronautical Research Council, Current Papers No. 46*, 1951 (January 30, 1950). 28 pp., illus. 2 references. British Information Services, New York. $1.15. Review of Tustin's method of dealing with time series and presentation of the analysis in matrix notation; application to the study of aircraft stability characteristics.

Flight Research with the Safir. *Saab Sonics*, No. 14, April–June, 1951, pp. 16–18, illus.

Use of the Saab-91 Safir as a research airplane; aerodynamic tests on the behavior of sweptback wings at low speeds. The wing and slot design of the Saab-29 jet fighter was tested on the Safir. Tests were also carried out on a new alcohol-spray deicing system for future aircraft.

A Summary and Analysis of Data on Dive-Recovery Flaps. Lee E. Boddy and Walter C. Williams. *U.S., N.A.C.A., Research Memorandum No. A7F09*, September 9, 1947. 40 pp., illus. A flight-test procedure.

Fuels & Lubricants (12)

Viscosity Conversion Charts. Nils M. Sverdrup. *Product Engineering*, Vol. 22, No. 8, August, 1951, pp. 179, 181, illus. Absolute and kinematic viscosity conversion charts.

Knock-Limited Power Outputs from a CFR Engine Using Internal Coolants. III—Four Alkyl Amines, Three Alkanolamines, Six Amides, and Eight Heterocyclic Compounds. Harry S. Imming and Donald R. Bellman. *U.S., N.A.C.A., Research Memorandum No. E6L05a*, February 3, 1947. 14 pp., illus. 3 references.

The Gas Turbine and Its Fuels. E. L. Bass, I. Lubbock, and C. G. Williams. (*World Petroleum Congress, 3rd*, The Hague, May 28–June 6, 1951.) *Shell Aviation News*, No. 156, June, 1951, pp. 14–23, illus.

Analysis of properties (specific gravity, distillation range, hydrocarbon composition, presence of sulphur compounds, cost, and availability) of gas-turbine fuels and their effects on gas-turbine performance; trends for future fuel developments; review of technical trends in the various fields of application of the gas-turbine power plant.

Limits of Flammability of Pure Hydrocarbon-Air Mixtures at Reduced Pressures and Room Temperature. James T. DiPiazza. *U.S., N.A.C.A., Research Memorandum No. E51C28*, May 25, 1951. 25 pp., illus. 18 references.

Study of the effect of molecular structure on the flammability limits of pure hydrocarbon-air mixtures. Results for 17 normal paraffins, branched paraffins, and mono-olefins are presented as flammability-limit curves.

Application of an Ultraviolet Spectrophotometric Method to the Estimation of Alkylnaphthalenes in 10 Experimental Jet-Propulsion Fuels. Alden P. Cleaves and Mildred S. Carver. *U. S., N.A.C.A., Research Memorandum No. E6K08*, April 30, 1947. 14 pp., illus. 4 references.

Fuel Tests on an I-16 Jet-Propulsion Engine at Static Sea-Level Conditions. Ray E. Bolz and John B. Meigs. *U.S., N.A.C.A., Research Memorandum No. E7B01*, April 29, 1947. 22 pp., illus.

Effect of Fuel on Performance of a Single Combustor of an I-16 Turbojet Engine at Simulated Altitude Conditions. Eugene V. Zettle, Ray E. Bolz, and R. T. Dittrich. *U.S., N.A.C.A., Research Memorandum No. E7A24*, July 3, 1947. 19 pp., illus. 3 references.

Investigation of Carbon Deposition in an I-16 Jet-Propulsion Engine at Static Sea-Level Conditions. Edmund R. Jonash, Henry C. Barnett, and Edward G. Stricker. *U.S., N.A.C.A., Research Memorandum No. E6K01*, April 29, 1947. 11 pp., illus. 1 reference.

Nomograph on Flow of Viscous Fluids; The Hagen-Poiseuille Law for Determining Pressure Drop in Laminar Flow of Viscous Fluids in Circular Conduits. Leonard M. Majeske. *Tool Engineer*, Vol. 27, No. 2, August, 1951, p. 39, illus.

Gliders (35)

The Development of the "Ross-Johnson 5" Sailplane. Richard Johnson. *Sailplane and Glider*, Vol. 19, No. 7, July, 1951, pp. 150–153, 164, illus. Design and development; performance; specifications.

Guided Missiles (1)

Step Multiplier in Guided Missile Computer. Edwin A. Goldberg. *Electronics*, Vol. 24, No. 8, August, 1951, pp. 120–124, illus. 1 reference.

The Project Typhoon 4,000-tube analog computer used in the design of complete missile systems simulates missile and target characteristics. Design and function of the major sections of the computer are explained. The step multiplier provides high precison with a reversible binary counter and relay-operated variable-conductance networks.

A Limiting Case for Missile Rolling Moments. Ernest W. Graham. (*Douglas Aircraft Company, Inc., Report No. SM-13812*, October 23, 1950.) *Journal of the Aeronautical Sciences*, Vol. 18, No. 9, September, 1951, pp. 624–628, illus. 8 references.

Evolution of the Guided Missile. IV—The New Research Instrument. Kenneth W. Gatland. *Flight*, Vol. 60, No. 2216, July 13, 1951, pp. 45–48, illus.

Review of U.S. work in high-altitude research using rockets; development of the WAC Corporal, the V-2, Aerobee, and Viking rockets; instrumentation research and means of receiving and recording data; recovery of instruments after flight.

Instruments (9)

Central Instrumentation Widens Testing Scope. Frank Friswold. *Product Engineering*, Vol. 22, No. 8, August, 1951, pp. 168–171, illus.

N.A.C.A. instrumentation system for testing rocket engines uses a concrete blockhouse to house test panels and recorders for instruments from eight test cells; the instruments and their functions.

Suction-Air Systems for Air-Operated Gyroscopic Instruments. O. E. Patton and Samuel Bryan. *U.S., Civil Aeronautics Administration, Airframe & Equipment Engineering Report No. 47*, July, 1951. 20 pp., illus. Types of systems; components and accessories; construction details; system design and installation; testing the suction-air system.

A Pneumatic Comparator of High Sensitivity. M. Graneek and J. C. Evans. *The Engineer*, Vol. 192, No. 4981, July 13, 1951, pp. 62–64, illus. 2 references. Design, operation, and calibration.

Capacitor Gages for Measuring Small Motions. Harry H. Schwartz. *Product Engineering*, Vol. 22, No. 8, August, 1951, pp. 163–165, illus.

Capacitor gages that convert a mechanical movement as small as 1 microin. into a measureable electric signal can be used to measure temperature, pressure, and dimensions. The design and operation of such gages, along with possible applications, are examined.

The Response of a Ball Crusher Gage. George Chertock. *U.S., Navy Department, David W. Taylor Model Basin, Report No. 751*, April, 1951. 9 pp., illus. 3 references.

Analysis of a Friction Damper for Clutch-Type Servomechanisms. Herbert K. Weiss. *Journal of the Aeronautical Sciences*, Vol. 18, No. 10, October, 1951, pp. 676–682, illus. 8 references.

Analysis, by tracing pairs of trajectories in the phase plane, of the transient and steady-state motion of a clutch-type servomechanism coupled by coulomb friction to an inertia element.

Aerodynamic Stability and Automatic Control. William Bollay. (*14th Wright Brothers Lecture.*) *Journal of the Aeronautical Sciences*, Vol. 18, No. 9, September, 1951, pp. 569–617, Discussion, pp. 617–623, 640, illus. 91 references.

Summary of recent developments, particularly the analytical and experimental methods that are used in the design of aircraft control systems. The dynamic analysis of automatic control systems is discussed, and the principal analytical methods are illustrated by examples. The use of electronic computers and of flight simulators are considered, as well as flight-testing techniques for automatic control systems. Future problems and applications are studied.

Inverted Servo System for Sensitive Inputs. Henry F. Colvin, III. *Product Engineering*, Vol. 22, No. 8, August, 1951, pp. 147–151, illus. General analysis of synchro servosystems, including circuit designs; standards for the design of inverted systems.

Experimental Study of an Angle-of-Attack Vane Mounted Ahead of the Nose of an Airplane for Use as a Sensing Device for an Acceleration Alleviator. Christopher C. Kraft, Jr., and Arthur Assadourian. *U.S., N.A.C.A., Technical Note No. 2415*, July, 1951. 8 pp., illus. 1 reference.

Tests to determine if a vane mounted ahead of the nose of an aircraft gives the average angle of attack over the entire wing span. Flight tests were made at 150 m.p.h. in moderately rough air.

Collins Combines Flight Instruments; Newly Designed Approach Horizon, Course Indicator Simplify ILS and Omni-Range

Flying. *American Aviation*, Vol. 15, No. 10, August 6, 1951, p. 24, illus.

Readers' Forum: Small Pitot Tubes with Fast Pressure Response Time. W. S. Bradfield and G. E. Yale. *Journal of the Aeronautical Sciences*, Vol. 18, No. 10, October, 1951, pp. 697, 698, illus. 7 references. Design and construction of a pitot tube with an opening 1 mil high, which will come to equilibrium in 5 to 20 sec.

High-Speed Wind-Tunnel Investigation of the Effects of Compressibility on a Pitot-Static Tube. Louis S. Stivers, Jr., and Charles N. Adams, Jr. *U.S., N.A.C.A., Research Memorandum No. A7F12*, August 4, 1947. 23 pp., illus. 2 references.

A Recording System for Flight Test Data. P. A. Hufton, F. G. R. Cook, and P. S. Saunders. *Gt. Brit., Aeronautical Research Council, Current Papers No. 44*, 1951 (December 20, 1949). 13 pp., illus., folding chart. 2 references. British Information Services, New York. $0.50.

Analysis of the difficulties encountered in reading flight-test data from film recordings; form of record and recording apparatus. The proposed recording system uses a transmission system from the instrument by which the readings are recorded in the binary digital system. The record is transcribed in the form of tabulated results or in punched-tape form for use in a sequence-controlled calculator.

Self-Balancing Strain Gauge Equipment. Alvin B. Kaufman. *Radio & Television News*, Vol. 46, No. 2, August, 1951, *Radio-Electronic Engineering*, pp. 12–14, illus. 2 references. Design techniques, equipment, and circuits of balancing-type electronic recorders for strain-gage-indicated stresses.

Stress-Strain Recorder. *Electronics*, Vol. 24, No. 8, August, 1951, pp. 244, 246, illus.

An electronic recorder that automatically records stress-strain or load deflection characteristics of aircraft armament equipment mechanisms. It consists of a measuring head and a recorder and is sensitive to deflections from 0.0001 in. to 10 in.

A Simple Type of *X(t)-Y* Recorder. Thomas A. Perls and W. A. Wildhack. *Review of Scientific Instruments*, Vol. 22, No. 7, July, 1951, pp. 541, 542, 2 references.

Investigation of the Utility of an Electronic Analog Computer in Engineering Problems. D. W. Hagelbarger, C. E. Howe, and R. M. Howe. *Michigan, University, Aeronautical Research Center, External Memorandum No. UMM-28*, April 1, 1949. 213 pp., illus. 19 references.

Study of the applicability of the computer to applied research. A simple servomechanism is simulated with the analog computer, and the step response, steady-state frequency response, and transient response of the servomechanism are determined. Computer setups are shown for each case. A summary of the theory of servomechanisms is included. As a further test of computer applicability, a more complicated servomechanism problem, that of the control of an airplane in elevation or pitch by means of an autopilot, was studied. The problem embodied the typical features of an airplane control problem.

Use of the Piezoelectric Gauge for Internal Friction Measurements. J. Marx. *Review of Scientific Instruments*, Vol. 22, No. 7, July, 1951, pp. 503–509, illus. 27 references.

Analysis of a driver-gage procedure for measurements in the kilocycle range gives almost instantaneous values of amplitude-dependent decrements. A driver-gage crystal combination is cemented together, and the test specimen is attached to the other end of the driver. The experimental technique is explained, and a numerical evaluation is carried out for a driver-gage of 18.5° X-cut quartz bars.

Dynamic Strain Measurement. C. M. Hathaway and K. C. Rock. *Electrical Engineering*, Vol. 70, No. 8, August, 1951, pp. 675–678, illus.

Electric methods and equipment used in dynamic strain measurements. Reluctance and resistance types of strain gages, the recording oscillograph, and associated equipment are explained.

Some Thermocouple Details for Temperature Measurement. Howard W. Cole, Jr. *Product Engineering*, Vol. 22, No. 8, August, 1951, pp. 166, 167, illus. Construction, insulation, applications, table of thermocouple materials and characteristics.

Electrically Excited Resonant-Type Fatigue Testing Equipment. Thomas J. Dolan. *American Society for Testing Materials, Bulletin*, No. 175, July, 1951, pp. 60–68, illus. 12 references.

Principal details and diagrams of the operating circuits and the control and shut-off mechanisms of a fatigue-testing machine. The machine operates essentially as an electrically operated tuning-fork; the amplitude is electrically controlled. The loads are applied by inertia forces.

A Bar-Magnet Velocity Meter. Thomas A. Perls and Erich Buchmann. *Review of Scientific Instruments*, Vol. 22, No. 7, July, 1951, pp. 475–481, illus. 7 references.

Theoretical and experimental analysis of a velocity meter consisting of a long bar magnet that moves relative to a long coil. The meter is used for studying vibration and shock motions. The linearity, sensitivity, frequency response, and overall characteristics of the meter were studied. Alnico V is the best material for the magnet. Installation procedures are given for measuring relative or absolute velocity.

Machine Elements (14)

Stresses Imposed by Processing. O. J. Horger. *SAE Quarterly Transactions*, Vol. 5, No. 3, July, 1951, pp. 393–403, illus. 27 references.

Analysis of residual thermal and/or transformation stresses developed in heat-treating operations, considering only stresses of the macroscopic type; the production, measurements, and evaluation of the influence of initial stresses on the service performance of axles and shafts.

BEARINGS

Investigation of 75-Millimeter-Bore Cylindrical-Roller Bearings at High Speeds. III—Lubrication and Cooling Studies—Oil Inlet Distribution, Oil Inlet Temperature, and Generalized Single-Oil-Jet Cooling Correlation Analysis. E. Fred Macks and Zolton N. Nemeth. *U.S., N.A.C.A., Technical Note No. 2420*, July, 1951. 49 pp., illus. 9 references.

FASTENINGS

Wave Effects in Isolation Mounts. M. Harrison and A. O. Sykes. *U.S., Navy Department, David W. Taylor Model Basin, Report No. 766*, May, 1951. 98 pp., illus. 10 references.

Theoretical and experimental analysis of the actual behavior of isolation mounts in terms of wave effects, considering the mounts to be acoustic transmission lines with traveling and standing waves.

FRICTION

On Rolling Friction. Tarô Hisada. *Japan Science Review*, Vol. 1, No. 4, December, 1950, pp. 1–10, illus. 11 references. Experimental study of the mechanism of rolling friction.

GEARS & CAMS

Cycloidal Cam Charts for Maximum Pressure Angle. A. Lengyel and A. H. Church. *Product Engineering*, Vol. 22, No. 8, August, 1951, pp. 183, illus.

Materials (8)

New Devices Speed Metal Fatigue Tests. *U.S., National Bureau of Standards, Technical News Bulletin*, Vol. 35, No. 7, July, 1951, pp. 103–105, illus.

Newly developed auxiliary fatigue-testing equipment includes deflection-response and vibration-responsive devices to stop the test machine when a small crack forms in the test specimen, polishing apparatus for test specimens, and a machine for fatigue-testing thin sheet specimens in bending.

CERAMICS & CERAMALS

Study of Chromium-Frit-Type Coatings for High-Temperature Protection of Molybdenum. D. G. Moore, L. H. Bolz, J. W. Pitts, and W. N. Harrison. *U.S., N.A.C.A., Technical Note No. 2422*, July, 1951. 39 pp., illus. 7 references. Results of oxidation and flame tests, at temperatures of 1,500°–3,000°F., of the durability of chromium frit-type coatings bonded to molybdenum.

High-Temperature Ceramic Materials. H. B. Michaelson. *Product Engineering*, Vol. 22, No. 8, August, 1951, pp. 120–123, illus. 12 references. Types, properties, and uses.

METALS & ALLOYS

The Fatigue Strength of Metallic Materials Under Alternating Stresses of Varying Amplitude. Toshio Nishihara and Toshiro Yamada. *Japan Science Review*, Vol. 1, No. 3, September, 1950, pp. 1–6, illus. 4 references.

Development of the basic theory and of a calculation method for the fatigue strength. Experimental apparatus was devised to test smooth and notched specimens of mild steel, hard steel, and duralumin under alternating stress loads. Test results are compared with calculated values.

Cyclic Engine Test of Cast Vitallium Turbine Buckets. I. J. Elmo Farmer, F. N. Darmara, and Francis D. Poulson. II. J. Elmo Farmer, George C. Deutsch, and Paul F. Sikora. *U.S., N.A.C.A., Research Memorandums Nos. E7J23, E7J24*, February 19, January 12, 1948. 45, 30 pp., illus. 2 references.

Studies on the Electrolytic Polishing. Sakae Tajima. *Japan Science Review*, Vol. 1, No. 4, December, 1950, pp. 49–60, illus. 43 references.

Summary of the author's research on electrolytic polishing, 1944–1949. Topics covered include studies on the chemical action of various bath substances and their effects on various metals, the nature of electropolished surfaces, mechanism of electropolishing, and Japanese applications of the process.

High-Temperature Problems in Aircraft Jet Engines and Turbo-Superchargers. R. B. Johnson. (*Metal Progress*, Vol. 59, No. 4, April, 1951, pp. 503–510.) *The Engineers' Digest*, Vol. 12, No. 7, July, 1951, pp. 223–225, illus. Problems in the fabrication and design of high-temperature metals; causes of failures; manufacturing precautions.

The General Tensional Relaxation Properties of a Bolting Steel. D. N. Frey. *American Society of Mechanical Engineers, Transactions*, Vol. 73, No. 6, August, 1951, pp. 755–760, illus. 3 references.

Measurement of the tensional relaxation properties of Cr-Mo-Si-Va bolting steel at 1,000°F. under varying conditions of elastic follow-up by means of a step-down relaxation test; comparison of these results with those of a true relaxation test carried out on a Barr and Bardgett test unit.

What Do You Know About Stainless? II. Howard E. Boyer. *Steel Processing*, Vol. 37, No. 7, July, 1951, pp. 345–348, illus. 3 references.

Some Notes on Gas Holes in Iron Castings Cast in Green Sand Mould. Toshihiro Kinoshita and Michio Ogata. *Japan Science Review*, Vol. 1, No. 4, December, 1950, pp. 75–80, illus.

An Introduction to Arc-Cast Molybdenum and Its Alloys. J. L. Ham. *American Society of Mechanical Engineers, Transactions*, Vol. 73, No. 6, August, 1951, pp. 723–732, illus. 10 references. Advantages and limitations of the arc-casting method; general properties of unalloyed cast Mo; requirements for and selection of alloying elements; hardness control; applications.

A New Electrolytic Polishing Method for Metallographic Investigations of Si-Rich Light Alloys. E. Knuth-Winterfeldt. (*Revue de l'Aluminium*, Vol. 28, No. 175, March, 1951, pp. 84–86.) *The Engineers' Digest*, Vol. 12, No. 7, July, 1951, p. 222, illus.

NONMETALLIC MATERIALS

The Engineering Properties of Silicone Rubbers. P. C. Servais. *Mechanical Engineering*, Vol. 73, No. 8, August, 1951, pp. 639–643, illus. Thermal stability and dielectric properties of Silastic (Dow Corning silicone rubber), limitations, applications.

Neoprene Applications in Engineering Design. R. W. Malcolmson. *Mechanical Engineering*, Vol. 73, No. 8, August, 1951, pp. 627–632, 643, illus.

PROTECTIVE COATINGS

Alodizing Navy Cutlass Fighters Against Corrosion. *Automotive Industries*, Vol. 105, No. 3, August 1, 1951, pp. 38, 39, 78, illus.

Stages in the Alodizing process, advantages of Alodizing, inspection standards, refinishing of rejected parts. A flow chart shows the sequence of operations and data on the process.

SANDWICH MATERIALS

The Evaluation of Theoretical Critical Compression in Sandwich Plates. J. N. Goodier and I. M. Neou. *Journal of the Aeronautical Sciences*, Vol. 18, No. 10, October, 1951, pp. 649–656, 664, illus. 11 references. Evaluation of the range of validity of several simple solutions and comparison with exact solution.

Military Aviation (24)

Structure of the Red Air Force. *Aviation Age*, Vol. 16, No. 1, July, 1951, pp. 33, 34, illus.

Navigation (29)

Air Navigation by Radar in Southeastern Alaska. R. C. Borden. *U.S., Civil Aeronautics Administration, Technical Development Report No. 65*, February, 1951. 13 pp., illus. Installation and service tests of APS-10 air-borne radar equipment in a Grumman JRF-6B seaplane.

Swissair's Navigator. *The Aeroplane*, Vol. 81, No. 2085, July 6, 1951, p. 19, illus.

The Swissair Navigator consists of four hinged metal plates. The two circular plates are the four-part plate that carries the circular slide rules, including conversion tables for English and American measurements and metric measurements and the directional disc that has a protractor for measuring vectors. The other two semicircular discs carry directions and computational procedure.

Power Plants

Russian Powerplants. Paul H. Wilkinson. *Aviation Age*, Vol. 16, No. 1, July, 1951, pp. 50, 51, illus. Reciprocating and gas-turbine power plants—development, types, and production.

An Analysis of a Highly Compounded Two-Stroke-Cycle Compression-Ignition Engine. Max J. Tauschek, Bernard I. Sather, and Arnold E. Biermann. *U.S., N.A.C.A., Research Memorandum No. E8L09*, April 4, 1949. 51 pp., illus. 16 references.

An Analysis of a Piston-Type Gas-Generator Engine. Max J. Tauschek and Arnold E. Biermann. *U.S., N.A.C.A., Research Memorandum No. E7I10*, February 18, 1948. 33 pp., illus. 15 references.

Computed Performance of a Composite Engine Based on Experimental Data for a Single-Cylinder Conventional Aircraft Engine Converted to Compression-Ignition Operation. J. Arnold McCoy and Frank Szel. *U.S., N.A.C.A., Research Memorandum No. E7B03*, February 3, 1947. 19 pp., illus. 5 references.

Experimental Study of Loop-Scavenged Compression-Ignition Cylinder for Gas-Generator Use. Hampton H. Foster, F. Ralph Schuricht, and Max J. Tauschek. *U.S., N.A.C.A., Research Memorandum No. E8L30*, April 4, 1949. 45 pp., illus. 9 references.

Preliminary Evaluation of the Performance of a Uniflow Two-Stroke-Cycle Spark-Ignition Engine Combined with a Blowdown Turbine and a Steady-Flow Turbine. Bernard I. Sather and Hampton H. Foster. *U.S., N.A.C.A., Research Memorandum No. E7D29*, November 25, 1947. 49 pp., illus. 12 references.

The Calculated Performance of a Jet Propulsion Device with a Regenerator, System PCETXJ. Joseph H. Keenan, Ascher H. Shapiro, and Carol A. Rieke. *U.S., N.A.C.A., Advance Confidential Report No. 5B01 (Declassified)*, April, 1945. 25 pp., illus. 5 references.

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Systems CET, CEHT, and CETX; Analysis of a Power Plant of High Efficiency and Great Overload Capacity. Joseph H. Keenan, Ascher H. Shapiro, Joseph Kaye, and Carol A. Rieke. *U.S., N.A.C.A., Advance Confidential Report No. 3H31 (Declassified)*, August, 1943. 42 pp., illus. 6 references.

JET & TURBINE (5)

Combustion Problems of the Gas Turbine. I. Lubbock. (*North-East Coast Institution of Engineers and Shipbuilders, Trans-*

actions, Vol. 67, 1951, pp. 131–154.) *Aircraft Engineering*, Vol. 23, No. 269, July, 1951, pp. 196–202, 213, illus. 16 references. Analysis of the effects of fuel grade, fuel atomization, combustion air distribution, and air flow pattern on combustion and on the design aspects of the burner and combustion chamber.

Turbojet and Turboprop Engine Controls. F. C. Mock. *SAE Quarterly Transactions*, Vol. 5, No. 3, July, 1951, pp. 376–392, illus. 4 references. Functional requirements of jet controls; the relationship of the control system to the engine and airplane; design difficulties due to military specifications.

Cooling of Gas Turbines. III—Analysis of Rotor and Blade Temperatures in Liquid-Cooled Gas Turbines. W. Byron Brown and John N. B. Livingood. **IV—Calculated Temperature Distribution in the Trailing Part of a Turbine Blade Using Direct Liquid Cooling.** W. Byron Brown and William R. Monroe. **VI—Computed Temperature Distribution Through Cross Section of Water-Cooled Turbine Blade.** John N. B. Livingood and Eldon W. Sams. *U.S., N.A.C.A., Research Memorandums Nos. E7B11c, E7B11d, E7B11f*, February 11, April 18, May 1, 1947. 24, 43, 18 pp., illus. 9 references.

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Comparison of Some Turboprop Cycles for Subsonic Speeds. Tibor F. Nagey. *SAE Quarterly Transactions*, Vol. 5, No. 3, July, 1951, pp. 316–326, illus. 5 references.

General Treatment of Compressible Flow in Ejectors and Example of Its Application to Problem of Effect of Ejector Addition on Thrust of Jet-Propulsion Units. Herman H. Ellerbrock, Jr. *U.S., N.A.C.A., Research Memorandum No. L6L23*, June 16, 1947. 72 pp., illus. 14 references.

Theoretical Investigation of Thrust Augmentation of Turbojet Engines by Tail-Pipe Burning. H. R. Bohanon and E. C. Wilcox. *U.S., N.A.C.A., Research Memorandum No. E6L02*, January 28, 1947. 46 pp., illus. 2 references.

Performance Possibilities of the Turbojet System As a Power Plant for Supersonic Airplanes. George P. Wood. *U.S., N.A.C.A., Research Memorandum No. L7HO5a*, August 26, 1947. 59 pp., illus. 7 references.

Cyclic Engine Test of Cast Vitallium Turbine Buckets. I. J. Elmo Farmer, F. N. Darmara, and Francis D. Poulson. **II.** J. Elmo Farmer, George C. Deutsch, and Paul F. Sikora. *U.S., N.A.C.A., Research Memorandums Nos. E7J23, E7J24*, February 19, January 12, 1948. 45, 30 pp., illus. 2 references.

RAM-JET & PULSE-JET

A Cheap Power Unit for Light Aircraft. III. Peter Kahn and F. Clay. *The Aeroplane*, Vol. 81, No. 2087, July 20, 1951, pp. 75, 76, illus. Performance analysis of two- and four-place personal planes driven by a ram-jet-powered propeller.

RECIPROCATING (6)

Flight Comparison of Performance and Cooling Characteristics of Exhaust-Ejector Installation with Exhaust-Collector-Ring Installation. Loren W. Acker and Kenneth S. Kleinknecht. *U.S., N.A.C.A., Research Memorandum No. E6L13a*, February 14, 1947. 36 pp., illus. 4 references.

The Development of the de Havilland Series of Engines for Light Aircraft. J. L. P. Brodie. (*Paper Presented Before the Institution of Mechanical Engineers*, April 10, 1951.) *de Havilland Gazette*, No. 63, Supplement, June, 1951, pp. 3–16, illus.

Chronological review of the design development of the de Havilland light engines. Emphasis is placed on crankshaft design development. Photographs show the engines and the planes powered by the de Havilland Gipsy series of engines.

Design Features of the Nordberg Radial Engine. D. I. Bohn and Emil Grieshaber. *American Society of Mechanical Engineers, Transactions*, Vol. 73, No. 6, August, 1951, pp. 795–800, Discussion, pp. 800–802, illus.

Effect of Modifications to Induction System on Altitude Performance of the V-1710-93 Engine. III—Use of Parabolic Rotating Guide Vanes and NACA-Designed Auxiliary-Stage Inlet Elbow and Interstage Duct. Ray M. Standahar and James S. McCarty. *U.S., N.A.C.A., Research Memorandum No. E6L27*, January 16, 1947. 24 pp., illus. 6 references.

ROCKET (4)

A Method of Selecting Rocket Thrust for Experimental Supersonic Airplanes. Robert W. Byrne. *U.S., N.A.C.A., Restricted Bulletin No. L6G22 (Declassified)*, August, 1946. 11 pp., illus.

Central Instrumentation Widens Testing Scope. Frank Friswold. *Product Engineering*, Vol. 22, No. 8, August, 1951, pp. 168–171, illus.

N.A.C.A. instrumentation system for testing rocket engines uses a concrete blockhouse to house test panels and recorders for instruments from eight test cells. Measurements common to all cells and transmitted as electric signals are recorded in the blockhouse. Bourdon tube recorders, pneumatically operated controllers, and specialized instrumentation are located in the test cells.

Production (36)

How Airframe Design Trends Affect Manufacturing Methods. Alfred H. Petersen. *Automotive Industries*, Vol. 105, No. 3, August 1, 1951, pp. 52, 53, 102, illus. Production techniques for integrally stiffened structures.

The USSR's Aircraft Industry. *Aviation Age*, Vol. 16, No. 1, July, 1951, pp. 52–54, illus. 1 reference. Organization, production capacity and techniques, man power available, dispersal of facilities, materials reserves.

Ultrasonic Inspection Today. H. E. Van Valkenburg. *Tool Engineer*, Vol. 27, No. 2, August, 1951, pp. 36–38, illus. Brief review of development and research in ultrasonic testing; general features of ultrasonic inspection.

Power Flexibility for Aircraft Production. *Automotive Industries*, Vol. 105, No. 3, August 1, 1951, pp. 49, 82, 84, illus. Use of compressed air as a power supply for hot-dimpling and flush-riveting operations at Douglas Aircraft Co., Inc.

Which Surface Hardening Process? Lester Spencer. *Product Engineering*, Vol. 22, No. 8, August, 1951, pp. 157–162, illus., folding chart.

The problem of steel selection; the case-carburizing processes; the nitriding method and characteristics of the resulting surface; flame and induction hardening. A case-hardening selection chart classifies the basic characteristics of each type of case and lists the advantages and disadvantages of each process.

Designing Pattern Dies for Investment Casting. I. Rawson L. Wood and Davidlee Von Ludwig. *Tool Engineer*, Vol. 27, No. 2, August, 1951, pp. 25–28, illus. Design and mechanical considerations; materials used for wax pattern dies; selection of die material on the basis of weight, quantity needed, and pattern complexity.

Study on the Surface of Castings. Kazuo Katori. *Japan Science Review*, Vol. 1, No. 4, December, 1950, pp. 11–18, illus. 1 reference.

A roughness tester was designed and built to study the surface roughness of both the mold surface and the casting surface. Results are presented on tests on cast iron and aluminum that were cast in molds constructed of various sand sizes and compositions.

Metal Spinning. D. Reebel. (*Steel*, Vol. 128, No. 23, June 4, 1951, pp. 88–91.) *The Engineers' Digest*, Vol. 12, No. 7, July, 1951, pp. 215, 216, illus. Shapes that can be formed by spinning; advantages and limitations of fabrication by spinning; automatic spinning lathes.

Expanding Rubber Forms Parts. Thomas L. Self. *Aviation Week*, Vol. 55, No. 4, July 23, 1951, pp. 32, 34, 39, illus.

New technique, developed by Vic Pastushin Industries, Inc., for forming metal to complex contours is a hydraulic process using an internal expanding rubber die. The die is an $^3/_8$-in. thick, oil-resistant rubber bag capable of withstanding a pressure of 1,000 lbs. per sq.in. The die holder is Meehanite with a plastic liner.

A Comparison of Military Standard 105A with the 1944 Army Services Forces Sampling Procedures and Tables and with JAN-Standard 105. Seymour J. Lorber and Eugene L. Grant. *Industrial Quality Control*, Vol. 8, No. 1, July, 1951, pp. 27–29.

Tabulation of military standards for inspection of parts in which the acceptance or rejection of each lot of the product submitted depends on the inspection of samples from the lot.

Martin Speeds Plans for B-57 Production. Irving Stone. *Aviation Week*, Vol. 55, No. 4, July 23, 1951, pp. 19, 20, 22–24, 27, 28, 31, illus.

Production plans, including some design changes, conversion of British standards, and subcontracting for the B-57A—the English Electric Co. Ltd. Canberra—at The Glenn L. Martin Co. The twin-jet B-57A will be used as a night-intruder bomber.

Electroformed Tooling. M. H. Orbaugh. *Automotive Industries*, Vol. 105, No. 3, August 1, 1951, pp. 32, 33, 86, illus. Procedure and advantages for low-pressure laminates.

Propellers (11)

Air-Flow Surveys in the Vicinity of Representative NACA 1-Series Cowlings. Robert W. Boswinkle, Jr. *U.S., N.A.C.A., Research Memorandum No. L8A15a*, May 7, 1948. 94 pp., illus. 6 references.

Preliminary Investigation of Two Full-Scale Propellers To Determine the Effect of Swept-Back Blade Tips on Propeller Aerodynamic Characteristics. Albert J. Evans and E. Bernard Klunker. *U.S., N.A.C.A., Research Memorandum No. L6J21*, May 12, 1947. 56 pp., illus. 4 references.

An Investigation in the 40- by 80-Foot Wind Tunnel of Tip-Speed Effects on Propeller Characteristics in the Take-Off and Climbing Range. I—Four-Blade Curtiss X836-1C2-24 Propeller. Bradford H. Wick and Adrien E. Anderson. *U.S., N.A.C.A., Advance Confidential Report No. 5L12 (Declassified)*, February, 1946. 63 pp., illus. 12 references.

Investigation of Two-Blade Propellers as High Forward Speeds in the NACA 8-Foot High-Speed Tunnel. I—Effects of Compressibility. John Stack, Eugene C. Draley, James B. Delano, and Lewis Feldman. *U.S., N.A.C.A., Advance Confidential Report No. 4A10 (Declassified)*, January, 1944. 37 pp., illus. 7 references.

Reference Works (47)

DICTIONARIES & ENCYCLOPEDIAS

English-French Vocabulary of Aeronautical Terms; Based upon British Standard 185: 1950, Glossary of Aeronautical Terms. IV. M. Chalmette. *Aircraft Engineering*, Vol. 23, No. 269, July, 1951, pp. 207, 208.

Rotating Wing Aircraft (34)

Convertible Aircraft. III. J. S. Shapiro. *The Aeroplane*, Vol. 81, No. 2086, July 13, 1951, pp. 42-45, illus. 2 references. Theoretical investigation of the speed range and performance of combined rotary- and fixed-wing aircraft; possibilities of increasing helicopter speed; applications.

A Preliminary Theoretical Study of Aerodynamic Instability of a Two-Blade Helicopter Rotor. Robert P. Coleman and Carl W. Stempin. *U.S., N.A.C.A., Research Memorandum No. L6H23*, March 18, 1947. 14 pp., illus. 2 references.

Sciences, General (33)

MATHEMATICS

Investigation of the Utility of an Electronic Analog Computer in Engineering Problems. D. W. Hagelbarger, C. E. Howe, and R. M. Howe. *Michigan, University, Aeronautical Research Center, External Memorandum No. UMM-28*, April 1, 1949. 213 pp., illus. 19 references.

Study of the applicability of the computer to applied research. Computer circuits are presented for the solution of such problems as differential equations with one independent variable, simultaneous differential equations with constant coefficients, boundary-value problems, boundary-value problems with variable coefficients, methods of obtaining variable coefficients, and the solution of Bessel's equation to show the applications of the computer. Accuracy, stability, introduction of end conditions, and time required for the computation are considered in order to show the advantages and limitations. The computer, as set up, will handle only linear equations. The solution of vibrating-beam problems is demonstrated.

Further Application of the Electronic Differential Analyzer to the Oscillation of Beams. Carl E. Howe. **Appendix I—Closed-**

Loop Continuous Drift Compensation. L. L. Rauch. **Appendix II—Modification of the Brush DC Amplifier BL-913 for Use with an Electronic Differential Analyzer.** L. L Rauch and R. H. Dougherty. *Michigan, University, Aeronautical Research Center, External Memorandum No. UMM-47,* June 1, 1950. 54 pp., illus. 2 references.

Solution, using an electronic differential analyzer, of the problem of determining the normal modes of oscillation of a uniform free-free beam using as end conditions the equations to zero, at both ends, of the expressions for bending moment and shearing force. This solution considers the effects of shearing force and rotary inertia. This is an extension of the research reported in UMM-28.

Application of the Electronic Differential Analyzer to the Oscillation of Beams, Including Shear and Rotary Inertia. C. E. Howe, R. M. Howe, and L. L. Rauch. *Michigan, University, Aeronautical Research Center, Memorandum No. UMM-67,* January, 1951. 98 pp., illus., folding charts. 13 references.

Solution of a fourth-order differential equation subject to boundary conditions imposed by restraints, or lack of them, on the ends of a beam. The analyzer is used to determine the eigenfrequencies and mode shapes for vibrations of uniform and nonuniform beams, considering the effects of rotary inertia and transverse shear force. The results are presented in tables and curves. This work is a continuation of UMM-47.

A New Analog Computer. S. Bosworth. *Electronics,* Vol. 24, No. 8, August, 1951, pp. 216, 218, 220, 222, 224, illus.

Design and operation of the Computer Corp. of America's Integro-Differential Analyzer (IDA), a desk-sized, inexpensive computer that is capable of solving eighth-order differential equations. Solutions appear graphically on a magnetic oscillograph. Although housed in a single cabinet, it is possible to interconnect two or more computers or to introduce auxiliary equipment.

Step Multiplier in Guided Missile Computer. Edwin A. Goldberg. *Electronics,* Vol. 24, No. 8, August, 1951, pp. 120–124, illus. 1 reference.

The Project Typhoon 4,000-tube analog computer used in the design of complete missile systems simulates missile and target characteristics. Design and function of the major sections of the computer are explained. The step multiplier provides high precision with a reversible binary counter and relay-operated variable-conductance networks.

On the Solution of Ordinary Differential Equations with Digital Computing Machines. Carl-Erik Fröberg. (*Kunglika Fysiografiska Sällskapets i Lund, Forhandlingar,* Bd. 20, Nr. 11, 1950.) *Acta Polytechnica* (Stockholm), No. 79 (*Physics and Applied Mathematics Series,* Vol. 1, No. 9), 1950. 17 pp., illus. 9 references. Sw. Kr. 1:00. In English.

The Automatic Digital Computer at Manchester University. I-III. *The Engineer,* Vol. 192, Nos. 4981–4983, July 13, 20, 27, 1951, pp. 47–49; 91–93; 126–129, illus. 15 references.

An Introduction to Computer Concepts. I. John D. Goodell. *Radio & Television News,* Vol. 46, No. 2, August, 1951, *Radio-Electronic Engineering,* pp. 3–5, 30, illus. Basic principles; future potentialities.

The Simplest Form of Second-Order Linear Differential Equation, with Periodic Coefficient, Having Finite Singularities. Enzo Cambi. *Royal Society (Edinburgh), Proceedings, Series A, Mathematical and Physical Sciences,* Vol. 63, Part 1, No. 3, 1950, pp. 27–51, illus. 7 references. Reprint.

Number Series Method of Solving Linear and Non-Linear Differential Equations. Albert Madwed. (*Massachusetts Institute of Technology, Sc.D. Thesis.*) *Massachusetts Institute of Technology, Instrumentation Laboratory, Report No. 6445-T-26,* April, 1950. 238 pp., illus. 34 references.

The Number Series Method involves the representation of functions by a series of real numbers associated with various types of unit functions spaced at equal increments of the independent variable, *t*. The mathematical operations, as defined in terms of number series functions, are used for solving differential equations. Procedures for using the method are explained and illustrated. Criteria are developed for determining the stability and physical realizability of the constant-coefficient number-series equations and regression equations.

The Stability of Solutions of Non-Linear Difference-Differential Equations. E. M. Wright. *Royal Society (Edinburgh), Proceedings, Series A, Mathematical and Physical Sciences,* Vol. 63, Part I, No. 2, 1950, pp. 18–26. 16 references. Reprint.

Extension to nonlinear difference-differential equations of the theorems of the order of smallness, as the independent variable goes to $+\infty$, of solutions of differential equations having nonlinear perturbation terms.

Studies in Practical Mathematics. V—On the Iterative Solution of a System of Linear Equations. VI—On the Factorization of Polynomials by Iterative Methods. A. C. Aitken. *Royal Society (Edinburgh), Proceedings, Section A, Mathematical and Physical Sciences,* Vol. 63, Parts 1, 2, 1950, 1949–1950, pp. 52–60; 174–191. 15 references. Part V is reprint.

V. Study of the rapid convergence of iterative processes from the standpoint of matrices. A variant of the Seidelian process, based on an operator that, in a positive definite matrix, has real characteristic roots confined to $0 \leq \lambda < 1$ is presented and evaluated. **VI.** Extension of Lin's iterative method for approximating by stages to an exact factor of a polynomial.

Unbiased Statistics with Minimum Variance. A. Bhattacharyya. *Royal Society (Edinburgh), Proceedings, Section A, Mathematical and Physical Sciences,* Vol. 63, Part I, No. 6, 1950, pp. 69–77. 3 references. Reprint.

Circular Nomogram Theory and Construction Technique. Edward C. Varnum. *Product Engineering,* Vol. 22, No. 8, August, 1951, pp. 152–156, illus. 6 references.

Les Transformations Asymptotiquement Presque Périodiques Discontinues et le Lemme Ergodique (Première Note). Maurice Fréchet. *Royal Society (Edinburgh), Proceedings, Section A, Mathematical and Physical Sciences,* Vol. 63, Part I, No. 6, 1950, pp. 61–68. 4 references. Reprint. In French. Discontinuous asymptotically, almost periodic transformations and the ergodic theorem.

PHYSICS

Lattice Theories of the Liquid State. J. S. Rowlinson and C. F. Curtiss. *Wisconsin, University, Naval Research Laboratory, Department of Chemistry, Report No. CM-674,* June 13, 1951. 47 pp., illus. 27 references. Analysis of four modifications to the Lennard-Jones and Devonshire quantitative form of the lattice theory of liquids.

The Third Virial Coefficient of Polar Gases. J. S. Rowlinson. *Wisconsin, University, Naval Research Laboratory, Department of Chemistry, Report No. CM-661,* March 14, 1951. 15 pp., illus. 8 references.

Space Travel

Meteors and Space Travel. Michael W. Ovenden. *British Interplanetary Society, Journal,* Vol. 10, No. 4, July, 1951, pp. 176–180. Brief analysis of the density of meteoric material in interstellar space, based on present astronomical data.

Structures (7)

Allowable Compressive Stresses in Aircraft Structures. B. E. Gatewood and E. L. Williams. *Journal of the Aeronautical Sciences,* Vol. 18, No. 10, October, 1951, pp. 657–664, illus. 51 references.

An extension of the procedure of Cozzone and Melcon for using nondimensional buckling curves to obtain allowable buckling and column stress for plate elements in aircraft structures results in methods for determining allowable buckling and failure of plates, formed or extruded sections, and stiffened panels in the elastic and plastic regions. The allowable buckling and maximum compressive stresses are presented as curves specifically applicable to Al and Mg alloys.

Stresses Imposed by Processing. O. J. Horger. *SAE Quarterly Transactions,* Vol. 5, No. 3, July, 1951, pp. 393–403, illus. 27 references.

Analysis of residual thermal and/or transformation stresses developed in heat-treating operations, considering only stresses of the macroscopic type. Methods of measurement and the formation of residual stresses are examined. The analysis is applied to stresses in rotating shafts, considering the fracture plane, fading of the stress, and the residual-stress surface gradient.

An Experimental Determination of the Critical Bending Moment of a Box Beam Stiffened by Posts. Paul F. Barrett and Paul Seide. *U.S., N.A.C.A., Technical Note No. 2414,* July, 1951. 9 pp., illus. 3 references.

Readers' Forum: Shear Flow in a Thin-Skin Tapered Beam. H. W. Sibert. *Journal of the Aeronautical Sciences*, Vol. 18, No. 10, October, 1951, pp. 703, 704.

It is proved that a simple formula involving the shear force carried by the webs, which is sometimes used for the shear flow in a thin-skin tapered beam, is not valid in general but will give correct results under certain specified conditions.

Correspondence: A Note on the Buckling of Struts, by H. Lurie. F. J. Plantema, H. Waters, W. T. Koiter, J. M. Tusiesicz, and David B. Hall. **Author's Reply.** *Royal Aeronautical Society, Journal*, Vol. 55, No. 487, July, 1951, pp. 454–458, illus.

Stability of the Cylindrical Shell of Variable Curvature. K. Marguerre. (*ZWB, Forschungsbericht No. 1671*, September 16, 1942.) *U.S., N.A.C.A., Technical Memorandum No. 1302*, July, 1951. 64 pp., illus. 8 references.

Development of a calculation procedure for determining the buckling load of cylindrical shells of variable curvature under three types of loading: compression in axial direction of the shell, shear (torsion), and a combination of both. Values are obtained for a wing nose of a symmetric half-oval shape.

The Structure of Airy's Stress Function in Multiply Connected Regions. Giuseppe Grioli. (*Giornale di Matematiche*, Vol. 77, 1947, pp. 119–144.) *U.S., N.A.C.A., Technical Memorandum No. 1290*, July, 1951. 34 pp. 9 references.

Use of the Airy stress function in studying the elastic equilibrium of a plane system of any order of connectivity. The singularities of the Airy stress function in a general plane system are isolated and related, by their mechanical properties, to the elastic system. The decomposition of the Airy function is presented for two cases, satisfying the conditions of many-valuedness and single-valuedness for the required displacements. The results are obtained for a doubly connected system and extended to a system of any order of connectivity.

A New Theory Concerning the Yielding of Materials Based on Riemannian Geometry. Kazuo Konda. *Japan Science Review*, Vol. 1, No. 3, September, 1950, pp. 7–10. 4 references.

Development of a new theory and analytical procedure for studying the nature of the dislocation of elastic bodies. Elasticity is explained in the concepts of Riemannian space, and expressions are presented for the dislocation and yield points.

The Application of Plastic Theory to Bending. M. Ish-Horowicz. *Aircraft Engineering*, Vol. 23, No. 269, July, 1951, pp. 203–206, illus. 36 references.

An examination of the general principles involved in applying "limit design" to structural members assuming that in bending the transverse sections remain plane and the stress-strain functions follow the laws of pure compression and tension. The theory is explained, and the moment of resistance is calculated for sections subjected to pure bending. It is applied to analyses of simply supported beams and statically indeterminate beams of both plastic and ductile materials.

Propagation of Transverse Waves in Plates. Irwin Vigness. *U.S., Naval Research Laboratory, Washington, Report No. 3794*, January 17, 1951. 19 pp., illus. 10 references.

Experimental study. The central area of a circular plate was made to acquire a constant transverse velocity within a short time. Displacement-time records were made by streak-photography methods of the radial bending strains, radial middle-surface strains, and circumferential middle-surface strains. These records were used to analyze the behavior of the plate under several transverse wave conditions.

Plates Under Lateral Impact. K. Karis. (*Ingenieur-Archiv*, Vol. 10, 1939.) *U.S., Navy Department, David W. Taylor Model Basin, Translation No. 135*, April, 1951. 20 pp., illus. 13 references. Determination of the deflection of plates under the influence of falling bodies and study of impact phenomena.

Readers' Forum: Lateral Elastic Instability of Hat-Section Stringers. C. M. Tyler, Jr., and T. J. Walker. *Journal of the Aeronautical Sciences*, Vol. 18, No. 9, September, 1951, p. 633, illus. 1 reference. Adaptation of Goodman's two-constant method of determining the lateral instability of hat-section stringers to a calculation involving hinged-leg conditions.

Electrically Excited Resonant-Type Fatigue Testing Equipment. Thomas J. Dolan. *American Society for Testing Materials, Bulletin*, No. 175, July, 1951, pp. 60–68, illus. 12 references. Principal details and diagrams of the operating circuits and the control and shut-off mechanisms of a fatigue-testing machine.

Brittle Coatings for Stress Analysis. II. Greer Ellis. *Tool Engineer*, Vol. 27, No. 1, July, 1951, pp. 49, 50, illus.

Thermodynamics (18)

Solution of Certain Unsteady Heat Flow Problems by Relaxation Methods. A. Gilmour. *British Journal of Applied Physics*, Vol. 2, No. 7, July, 1951, pp. 199–204, illus. 6 references. Procedure for applying Southwell's relaxation methods to the unsteady heat transfer through a uniform plain slab or a spherical shell.

Availability and Irreversibility in Thermodynamics. Joseph H. Keenan. *British Journal of Applied Physics*, Vol. 2, No. 7, July, 1951, pp. 183–192, illus. 11 references.

Heat Transfer from High-Temperature Surfaces to Fluids. I—Preliminary Investigation with Air in Inconel Tube with Rounded Entrance, Inside Diameter of 0.4 Inch and Length of 24 Inches. Leroy V. Humble, Warren H. Lowdermilk, and Milton Grele. *U.S., N.A.C.A., Research Memorandum No. E7L31*, May 21, 1948. 29 pp., illus. 5 references.

Heat-Transfer and Boundary-Layer Transition on a Heated 20° Cone at a Mach Number of 1.53. Richard Scherrer, William R. Wimbrow, and Forrest E. Gowen. *U.S., N.A.C.A., Research Memorandum No. A8L28*, January 10, 1949. 68 pp., illus. 11 references.

Heat Transfer to a Fluid Flowing Turbulent in a Smooth Pipe with Walls at Constant Temperature. R. A. Seban and T. T. Shimazaki. *American Society of Mechanical Engineers, Transactions*, Vol. 73, No. 6, August, 1951, pp. 803–807, Discussion, pp. 807–809, illus. 10 references.

Comparison of heat-transfer coefficients obtained under conditions of constant wall temperature and of linear variation of wall temperature. Heat-transfer coefficients were obtained by an iterative method that uses the results of Martinelli as a first approximation.

Simulated Altitude Investigation of Stewart-Warner Model 906-B Combustion Heater. Frederick R. Ebersbach and Adolph J. Cervenka. *U.S., N.A.C.A., Research Memorandum No. E6L02a*, January 8, 1947. 27 pp., illus.

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Aeronautical Reviews — BOOKS

The Performance of Civil Aircraft

By F. B. Baker. London, Sir Isaac Pitman & Sons, Ltd.; New York, Pitman Publishing Corporation, 1951. 302 pp., figs. $8.50.

A brief outline of the contents of Mr. Baker's book will suffice to show that he has written an unusual work. It is divided into three parts. The first part, labeled "Preliminary," concerns itself with the basic laws of mechanics, aerodynamics, piston engines, and gas-turbine engines and reduces these laws to mathematical formulas. The second section is concerned with the performance of piston-engined aircraft. Among the elements considered are take-off and landing, temperature accountability, the three standard methods of cruise control, fuel reserves, flight planning, pay load, and some of the economics of air-line operation. Mr. Baker says of Part III, it "is concerned with aircraft having gas-turbine engines and is incomplete. In the present state of practical knowledge this is bound to be the case."

The book has suffered slightly at the hand of the proofreader. Figs. 63 and 65 have been reversed. A flight plan made up for a Shannon-Gander flight is introduced as a Gander-Prestwick flight. The oil-gasoline line on Fig. 84 is incomplete. A careful student should not be bothered by these details. He may be puzzled in some of the formulas where a conversion from gallons to pounds is involved unless he realizes that imperial gallons are being considered. It should be recognized that the book uses, as standards for performance, calculations established by I.C.A.O. and the British Air Registration Board. The basic concepts obviously are the same and should cause little trouble to anyone working with C.A.R. specifications.

The inclusion of automatic flap retraction in baulked landing calculations may appear novel to some American readers. This reviewer would have liked to see automatic feathering calculations included in the considerations of take-off performance. He was delighted to find this quotation from P. H. Hufton included in the discussion of temperature accountability: "It may well be, therefore, that actual tests of the aircraft under tropical conditions will be essential if we are to get the accurate information which we all need."

In the section on cruising, more detail on the proper selection and matching of maximum L/D, horsepower for minimum specific consumption, and r.p.m. for maximum propeller efficiency might have been in order where maximum range was being considered. The section on flight planning does not consider any of the short-cut methods such as scaling overall wind components directly off an upper-air chart, a valuable time saver for a preliminary analysis. The allowance for fuel reserves does not include any tolerance for errors in forecast winds. On the other hand, it does not consider the economy of proceeding to an alternate at reduced, maximum-range horsepower. The reviewer is interested in the allowance of 2 per cent for depreciation in air frame, not a universal practice. It happens to be exactly the depreciation currently being experienced in recent type transatlantic aircraft.

Baker does not make it sufficiently clear, in his section on the economics of a choice of range, that where he refers to "maximum profits," he is speaking of the maximum difference between fuel costs and receipts per voyage and not of the usual maximum difference between gross costs and receipts per mile or per hour. Actually this section is primarily concerned with developing the case for the use of in-flight refueling. In this regard, it might be well to consider the statement made to this reviewer several years ago by the head of one of the refueling groups. He said that he would refuse to consider refueling any commercial aircraft that was dependent upon his fuel for a safe landing. He had no doubts as to the effectiveness of his refueling methods, but he recognized the possibility of the failure of his crew or of the tanker aircraft before it became air borne. If this limitation is reasonable, it would eliminate some off-shore refueling and refueling over an airport closed to the air liner but open to a radar-equipped tanker.

The discussion of some of the economics of maintenance and of the collection and presentation of cost records is most timely. It can scarcely be said, however, that these present a complete picture. Using the writer's own example of the cost in time and material of replacing defective windows in pressurized aircraft and his conclusion that an increased rate of failure would be tolerated if it coincided with a decreased overall maintenance cost, one cannot help but feel that a passenger who suffered decompression as the result of a window failure might have an explosive effect upon the overall economics that far outweighed any economies that could be effected in the glazing department.

It is difficult for this reviewer to accept Baker's brief dismissal of the flying boat. It has been strongly advocated by one of the authorities whom he is pleased to quote on another matter, and it easily solves two of the problems he presents earlier in the book as unsolved; but it must be admitted that Mr. Baker has sided with the majority.

This book should prove of great interest to that large group of engineers just entering the aeronautical field from other spheres of engineering. It is not too much to say that operating crews and ground operations personnel should be fully familiar with all of the matter included in the book. In spite of the author's modesty as expressed in the introduction, it does seem as though he had written a book especially for them.

William M. Masland
Master Pilot, Pan American World Airways System

For information on I.A.S. Library Service Facilities, see page 87

Aircraft Designers' Data Book

By Leslie E. Neville. New York, McGraw-Hill Book Company, Inc., 1950. 534 pp., illus. $10.

This book can best be described as a miscellany of perspective sketches, photographs, and specification data interspersed with descriptive material. The designs included in the book are largely those that were flying during World War II; hence no information will be found on the new crop of jet aircraft. Nevertheless, frequent references to German, British, and Canadian designs, as well as those of the United States, provide interesting comparative data.

As explained in the Introduction, the volume constitutes a rearrangement of the design analysis material that appeared originally in *Aviation* magazine and in *Wings*. No pretense of originality is made, except in the selection of material from the many designs that have appeared in these magazines.

The book should prove useful to the young designer since it presents numerous ways in which designers have solved problems in wing structures, in landing gears, in control systems, and in the rest of the airplane. To us older heads who failed to save those old *Aviation* magazines while they were still being published, here is a representative and well-selected group of design details illustrated and arranged for easy reference.

The book is arranged in eleven chapters under the following headings: I—General Design Characteristics; II—Wing and Auxiliary Surface Design; III—Empennage Design; IV—Fuselage, Body, and Hull Design; V—Landing Gear Design; VI—Control Systems; VII—Fuel and Lubrication Systems; VIII—Power-Plant Installation; IX—Miscellaneous Design Details; X—Rotating-Wing Aircraft; and XI—Turbine Engines.

Typical of the chapters is V on Landing Gear Design. Photographs and illustrations are given for such varied airplanes as the Republic Seabee, the Japanese Zeke 32, the Messerschmitt Me-163, the North American P-51, the Ryan FR-1, the Bristol Beaufighter, the Douglas DC-6, and the Northrop B-35. The illustrations show the general geometry of each design, including the retracting linkage employed. In some cases considerable design detail is shown. The descriptive literature shows types of wheels and brakes, types of retracting power, and similar information.

In the chapter on Miscellaneous Design Details, some information is given on machine-gun installations and on cabin air conditioning.

The chapter on jet engines should be interesting to those not familiar with the more modern designs, but this field has developed so rapidly that the obsolescence of the designs presented is strikingly evident.

The appendixes contain specification data on Air Force and Navy aircraft; personal aircraft; Canadian, British, and French aircraft; U.S. transport aircraft; reciprocating engines; turbine engines; and propellers.

It is unfortunate that the book does not contain material on such important items in airplane design as electric and hydraulic systems. These have assumed such importance that it seems a shame to neglect them.

In conclusion, the material presented is well chosen. The book should be on every reference shelf used by design personnel. There is material valuable to the new designer, and the whole book is good for browsing by old designers.

C. L. Bates
Chief, Mechanical Design
Northrop Aircraft, Inc.

High Horizons

Daredevil Flying Postmen to Modern Magic Carpet—the United Air Lines Story. Frank J. Taylor. New York, McGraw-Hill Book Company, Inc., 1951. 198 pp., illus. $4.00.

The pioneering days of a new industry are often recorded more by fiction than by fact. In the case of the air transport industry, its glamorous aspects have supported much fiction in articles, books, and movies. The air transport industry is extremely fortunate in having such a book as *High Horizons*, based on fact and recording with meticulous care the details of many important milestones in the birth of an industry.

Those who have been associated with air transportation during the last ten to 25 years will find an evening with *High Horizons* most rewarding in reawakening old memories and confirming facts, in some instances, rumored but not previously confirmed.

Taylor's account of the air-mail cancellations of 1934 is one of the most concise and accurate reviews yet written on the bolt-out-of-the-blue that came to the air lines in 1934.

Another feature of the book, which will be of high interest to veterans of the business, is its detailed review of the personalities behind the founding, growth, and future planning of United Air Lines. Although the book is based primarily on United Air Lines, it brings along contemporary history of the industry itself which gives a broad base to each of the many new eras through which the air transport industry has passed.

Concerning the literary style of *High Horizons*, Taylor has done an excellent job of holding reader interest throughout the book. One strong factor in maintaining continuity of interest is undoubtedly the manner in which he has brought in, through discussions, as well as pictures, the personalities that were involved in the story he tells. Taylor subtitles his book the "United Air Lines Story," and he does a good job of covering the history of this company. He goes further in providing a basic history of the founding and early days of one of America's greatest national resources—its air transport industry.

R. Dixon Speas
U.S. Representative
A. V. Roe Canada Limited

Book Notes

AERODYNAMICS

Some Aspects of Fluid Flow. Papers Presented at a Conference Organized by the Institute of Physics at Leamington Spa, October 25–28, 1950, and Reports of the Conference Discussion Groups. London, Edward Arnold & Company, 1951. 292 pp., illus., diagrs. $9.50.

Contents: Group (I) Industrial Problems: Survey of Industrial Problems Involving Turbulent Mixing of Fluids, M. P. Newby and M. W. Thring. Survey of Industrial Problems Involving the Combined Flow of Fluids and Solids, R. L. Brown. Survey of Industrial Problems Involving the Pattern of Fluid Flow, W. A. Simmonds. Survey of Industrial Problems Involving the Hydromechanics of Fluid Flow, L. E. Prosser and R. C. Worster. Group (II) Fundamental Problems: Problems in the Atomisation of Liquids, H. L. Green. Boundary Layers and Skin Friction in a Compressible Fluid Flowing at High Speeds, A. D. Young. The Effect of Concentration on the Settling of Suspensions and Flow Through Porous Media, P. G. W. Hawkesley. Fluid Flow Through Beds of Granular Materials, H. E. Rose. Group (III) Techniques: Some Aspects of Fluid Flow in Orifices, Nozzles, and Venturi Tubes, H. E. Dall. Techniques for the Study of Fluid Flow, J. H. Chesters, I. M. O. Halliday, and R. S. Howes. Fluid Flow in Relation to the Manufacture of Steel, M. P. Newby. A New Aerodynamic Technique Employing Radon for Tracing Gas Flow in Hot Systems, R. Mayorcas and K. P. Perry. Group (IV) Applications of Present Knowledge and Techniques: Theory and Design of Simple Ejectors, R. A. Smith. The Laws of Motion of Particles in Fluids and Their Application to the Resistance of Beds of Solids to the Passage of Fluid, R. A. Mott. Turbulence Excitation on Ship Models, J. F. C. Conn. *Reports from Discussion Groups:* Discussion Group (1) Combined Flow of Fluids and Solids. Discussion Group (2) Fundamentals of Mixing and Flow Patterns. Discussion Group (3) Flow Problems in Industries Employing High Temperature Furnaces (steel, glass, etc.). Discussion Group (4) Flow Problems in the Process Industries (gas, oil, chemical, etc.). Discussion Group (5) Flow Problems in Industries Based on Steam Generation (Power Industries). Concluding Statement and Summary, M. W. Thring.

Hydro- und Aero-Dynamik. 2. Teil, Widerstand und Auftrieb. Herausgegeben von Ludwig Schiller. (Handbuch der Experimentalphysik, Herausg. von W. Wien und F. Harms, Band 4, Teil 2.) (Leipzig, Akademische Gesellschaft m.b.h., 1932.) Ann Arbor, Mich., J. W. Edwards, 1948. 443 pp., diagrs., $11.

This volume is particularly concerned with problems of drag and lift. The history of experimental hydrodynamics and aerodynamics is discussed by O. Flachsbart (pp. 1–61), with particular reference to resistance and drag. The production of smooth air streams in wind tunnels is discussed by Ludwig Prandtl (pp. 65–106). R. Seiferth and A. Betz describe investigations of airplane models in wind tunnels (pp. 109–208), and A. Betz discusses the forces and moments on bodies of revolution (pp. 209–234). H. Muttray discusses the experimental facts of drag without lift (pp. 235–338). Drop experiments with spheres and discs are discussed by L. Schiller, (pp. 339–390), and phenomena of bearing friction and lubrication are described by S. Kriessalt in the final chapter. The bibliographies and footnote references throughout are extensive.

Osnovi Aerodinamičkih Konstrukcija. Miroslav Nenadović. Belgrade, Jugoslavia, Izdavačko Preduzeće Narodne Republike Srbije, 1948–1951. 5 Vols., illus., diagrs. *Aeroprofili*, 1948, 2 Vols., 364, 608 pp.; *Elise*, 1949, 450 pp.; General volume, 1950, 666 pp.; *Prilog*, 1951, 79 pp.

The first of this series on aerodynamic design to be published were the two volumes on airfoils (*Aeroprofili*). The first of these discusses aerodynamic forces and moments, aerodynamic coefficients, theory and test results, wing characteristics, including biplanes, and the selection of airfoils. The second volume on airfoils is a compilation of tables and charts on approximately 600 airfoils. About two-thirds of these are N.A.C.A. airfoils, and about 50 are Russian. These data are largely from the literature up to about 1939. The volume on propellers (*Elise*) is intended for practical use, giving the basic data for aerodynamic calculations, experimental results, and design data. Variable-pitch devices are discussed in a separate chapter. The general volume discusses the atmosphere, aerodynamic forces and moments, the physics of fluid mechanics, experimental results, and their application to the design of monoplanes and biplanes. The supplementary volume (*Prilog*) contains tables of dimensions and performance of various European and American engines, airplanes, gliders, and helicopters.

AERONAUTICS

Investigations in Aeronautics. Department of Aeronautical Engineering. R. M. Rosenberg, Editor. (University of Washington, Engineering Experiment Station, Bulletin No. 118, Aeronautical Series No. 1.) Seattle, University of Washington Press, 1951. 119 pp., diagrs. $2.00.

Contents: Application of the Extended Karman-Tsien Method for the Generation of Conventional Airfoils in Two-Dimensional Subsonic Compressible Flow, Richard M. Mark. The Flat Plate Laminar Boundary Layer in a Steady Accelerated Compressible Fluid, Howard A. Stine. The Effect of Variable Viscosity and Thermal Conductivity on the High-Speed Plane Couette Flow of a Semirarefied Gas, T. C. Lin. A New Approach to the Design of Metering Pins in Oleo Struts, H. P. Durand and R. M. Rosenberg. Aileron Flutter in a Single Degree of Freedom, K. P. Abichandani and R. M. Rosenberg. Periodic Solutions of a Nonlinear Differential Equation, R. M. Rosenberg and A. J. Wang. The Influence of Axial Torques on the Critical Speeds of Uniform Shafts in Self-Aligning Bearings, R. M. Rosenberg. An Instability Problem Arising in Uniform Cantilevered Struts, Harold C. Martin. An Observation Regarding the Deflections of Uniform Swept Cantilevered Plates, H. J. Gursahaney and Harold C. Martin. The St. Venant Torsion Problem for the Hyperbolic Airfoil Cross Section, T. C. Lin and L. G. Whitehead. The St. Venant Torsion Problem for Cross Sections Consisting of One Lopp of the Hyperbolic Limacon, T. C. Yin and H. T. Yang.

AGRICULTURAL AVIATION

Air Applicator Information Series. Vol. 1, Knowing Agricultural Chemicals, 108 pp. Vol. 2, Understanding Crop Pests, 95 pp. Vol. 3, How to Spray and Dust, 112 pp. Vol. 4, Selecting Efficient Equipment, 92 pp. Vol. 5, Answers to Legal Problems, 56 pp. Vol. 6, Directory, Where to Find It, 68 pp. Portland, Oregon, 412 Scott Bldg., Air-Applicator Institute, 1951. 6 Vols., illus. $12.50.

This attractive series of books presents the first comprehensive description of materials, equipment, and procedures in agricultural aviation. The first volume covers insect-killing chemicals, weed killers, disease protectants, soil sterilants, growth regulators, and plant foods. Volume 2 deals with insect, weed, and fungus identification. Volume 3 covers timing, distribution computations, patterns, rates, good application practices, accident prevention, and preparation of materials. Volume 4 covers sprayers, dusters, types of aircraft, C.A.A. modification requirements, and recent experimental development. Federal and state laws and regulations are discussed in Volume 5. The final volume contains a directory of organizations and state and Federal officials, a bibliography of over 300 references, a directory of suppliers of equipment and chemicals, a glossary, and useful conversion tables.

Handbook of Agricultural Pest Control. Stanley F. Bailey and Leslie M. Smith. New York, 254 W. 31st St., Industry Publications, Inc., 1951. 191 pp. $3.25.

This book covers all aspects of pest control, including both ground and air operations. Section 1 deals with chemicals for various agricultural purposes, their physical and chemical properties, compatibility, containers, toxicology, and spray-oil specifications. The second section covers spray machines, including rates of delivery and rates of application, dusts and dusting; there is a chapter on aircraft, rates of application from the air, and mosquito control from the air. The final section covers data for mosquito-control operators and hazards and contains useful tables and a list of terms and symbols. The authors are, respectively, Professor and Associate Professor of Entomology at the University of California.

AIR TRANSPORTATION

Role of Irregular Airlines in United States Air Transportation Industry. Hearings Before a Subcommittee of the Select Committee on Small Business, 82nd Congress, 1st Session, Senate. Washington, U.S. Govt. Printing Office, 1951. 261 pp.

Report on Role of Irregular Airlines in United States Air Transportation Industry. By the Select Committee on Small Business, United States Senate. (U.S., 82nd Congress, 1st Session, Senate, Report No. 540.) Washington, U.S. Govt. Printing Office, 1951. 19 pp.

AIRPLANE DESCRIPTIONS

Our Fighting "Jets." C. B. Colby. New York, Coward-McCann, Inc., 1951. 47 pp., illus. $1.00.

Brief descriptions, three-view silhouettes, and photographs are presented of eleven U.S. Air Force fighters, five bombers, and six Navy fighters. Performance data, measurements, and armament are included.

EDUCATION & TRAINING

Adventures in Aviation Education. H. E. Mehrens, Director and Editor. Washington, American Council on Education in Cooperation with the U.S. Civil Aeronautics Administration, 1951. 401 pp., illus. $3.50.

The greater part of this research report consists of nearly 60 reports of elementary and secondary school teachers on experiments in aviation education in 27 selected school systems. The program was undertaken to incorporate aviation into existing curricula as a means of enriching classroom programs by the use of materials of current significance. The entire range of subject matter of the curriculum and all grades are included in the reports. There is a list of more than 350 books, with their grade-level classifications indicated, a list of about 90 films, and a list of 14 bibliographies for the teacher.

ELECTRONICS

Electronic Miniaturization. U.S., National Bureau of Standards, Engineering Electronics Section. (U.S., Bureau of Aeronautics, NAer 00685; Office of Technical Services, Publication No. PB-100,949.) Washington, U.S. Department of Commerce, Office of Technical Services, 1949. 192 pp., diagrs. $4.75.

Electronic Equipment Construction; New Objectives, New Techniques, New Components. Stanford Research Institute. (U.S., Office of Naval Research, Phase I, Task Order No. 3, Contract N7Onr-32103; Office of Technical Services, Publication No. PB-101,745.) Washington, U.S. Department of Commerce, Office of Technical Services, June 1, 1950. 300 pp., illus., diagrs. $7.00.

EQUIPMENT

HYDRAULIC

Aircraft Hydraulics. Prepared by Naval Air Technical Training Command for Publication by the Bureau of Naval Personnel. (NavPers 10332-A.) Washington, Supt. of Documents, 1951. 292 pp., illus., diagrs. $0.75.

FLIGHT OPERATING PROBLEMS

Landing and Taking-Off of Aircraft in Bad Weather. Lord Brabazon of Tara. (Gt. Brit., Parliament, Command Paper No. 8147.) London, H.M. Stationery Office, 1951. 20 pp. British Information Services, New York. $0.25.

The relative responsibilities of the aircraft commander; the operator and the airport authority are examined in deciding whether an aircraft can safely land at, or take off from, an airport in bad weather conditions. Conclusions are summarized, and a procedure is recommended for adoption. The regulations of various governments regarding ceiling and visibility minimums are summarized.

FUELS & LUBRICANTS

Aviation Gasoline and Its Component Hydrocarbons: Wartime Research (1940–1945). H. M. Smith, A. J. Kraemer, and H. M. Thorne. (U.S., Bureau of Mines, Bulletin No. 497.) Washington, Supt. of Documents, 1951. 79 pp., diagrs., folded charts. $1.50.

Symposium on Methods of Measuring Viscosity at High Rates of Shear. (Special Technical Publication No. 111.) Philadelphia, American Society for Testing Materials, 1951. 47 pp., diagrs. $1.35.

Contents: Introduction, J. C. Geniesse. Viscosity-Shear Behavior of Two Non-Newtonian Polymer-Blended Oils, M. R. Fenske, E. E. Klaus, and R. W. Dannenbrink. The Kingsbury Tapered-Plug Viscometer for Determining Viscosity Variations with Temperature and Rate of Shear, S. J. Needs. The Comparison of Viscosity-Shear Data Obtained with the Kingsbury Tapered Plug Viscometer and the PRL High Shear Capillary Viscometer.

Properties of Lubricating Oil and Engine Deposits. C. A. Bouman. London and New

York, The Macmillan Company, 1950. 170 pp., diagrs. $3.00.

The first eight chapters (59 pages) deal briefly with the classification, manufacture, viscosity, volatility, and laboratory examination of lubricating oils; lubrication and friction of sliding metals, journal bearings, and pistons and cylinders; and lubricating-oil consumption. Following a chapter on cylinder wear, the discussion takes up in detail the contamination of lubricating oil, and sludge, carbon, and lacquer engine deposits. The final chapters deal with piston-ring sticking, maintenance, and the practical testing of lubricating oils. Test results are used from the Delft Laboratory of the Royal Dutch-Shell Group, with which the author is associated. The book is a translation from the Dutch, with modifications in specifications to meet British and American practice.

Physical Chemistry of Lubricating Oils. A. Bondi. New York, Reinhold Publishing Corporation, 1951. 380 pp., diagrs. $10.

The basic theory of lubricating oils is presented with particular emphasis on the theoretical relationships of the various physical properties and the relations between physical property and chemical structure. Following an opening chapter on Pressure-Volume-Temperature Properties, there are extended discussions of Rheology (83 pages), Surface Phenomena (66 pages), Optical and Electrical Properties (40 pages), Reaction Kinetics (63 pages), and chapters on The Hydrocarbon Type Analysis of Lubricating Oils and Phase Equilibria. The final chapter deals with Synthetic Lubricants. Over 675 references are given at the ends of chapters. The author is associated with the Shell Development Company at Emeryville, Calif.

INSTRUMENTS

The Handbook of Measurement and Control. Edited by M. F. Behar. Pittsburgh, The Instruments Publishing Company, Inc., 1951. 288 pp., illus., diagrs. With $3.00 subscription to *Instruments* magazine only.

Contents: Principles, Properties, and Things Common to All Instruments, M. F. Behar. Thermometry, M. F. Behar. Pyrometry, M. F. Behar. Automatic Control of Temperature, P. R. Ewald. Flow-Rate Measurement and Control, R. L. Galley. Positive Liquid and Gas Meters, M. F. Behar and L. M. Suckfield. Pressure and Vacuum, M. F. Behar. Speed Measurement and Control, M. F. Behar. Instrumentation for Chemical Analysis and Control, A. L. Chaplin. Determining Physical Properties and Testing Finished Products, H. C. Roberts. Electrical Instruments and Regulation, H. N. Hayward. Dimensional Gaging and Inspection, R. L. Geer. Control Valves and Their Applications, L. H. Allen, Jr. Instrumentation in Research, A. H. Peterson. Aviation Instruments, W. G. Brombacher. Nucleonics Instrumentation, F. G. Fox and R. B. Sutton.

Mariner's Gyro-Navigation Manual for Masters, Mates, Marine Engineers and Potential Ship's Officers. Walter J. O'Hara. Cambridge, Md., Cornell Maritime Press, 1951. 164 pp., illus. $3.50.

This book is designed for personnel who operate and maintain gyroscopic compass equipment on shipboard. It is based upon the author's lectures at the Sperry Marine School and in a laboratory course at the U.S. Merchant Marine Academy and is intended as a text and reference work intermediate between the usual discussion in navigation textbooks and the theoretical works on gyrodynamics.

LAWS & REGULATIONS

Economic Regulation of Scheduled Air Transport, National and International. A. J. Thomas, Jr. Buffalo, Dennis & Company, Inc., 1951. 274 pp. $10.

In the first two chapters (pp. 1–46), Federal legislation and activities up to 1938 and the constitutional basis for the regulation of civil aviation are reviewed. The economic regulation of do-

mestic air lines is reviewed in the third chapter and of international air lines in the fourth chapter. Domestic air line regulation is considered by a review of decisions of the Civil Aeronautics Board. The real problem is concluded to be one of correcting routes that have proved themselves to be weak economically. Within the framework of private enterprise and balanced competition, the Civil Aeronautics Act of 1938 is considered to be basically sound. The final chapter discusses international regulation of air transport, with particular attention to the stumbling block of air-space sovereignty and U.S. regulation of both American and foreign air carriers. Bilateralism is considered to be unsatisfactory. Ultimately, an international body with economic regulatory authority should be made responsible for the granting of operating rights and rates and guarding against unfair practices of nations and operating companies. The book is thoroughly documented from treatises, articles, cases, and administrative decisions and is extremely well indexed. The author is Associate Professor of Law at the Southern Methodist University.

Civil Air Regulations and Reference Guide for Pilots. Los Angeles, Aero Publishers, Inc., 1951. 130 pp. $1.50.

The text of Parts 1, 20, 21, 29, 43, 49, 60, and 62 of the *Civil Air Regulations*, Parts 501, 502, and 503 of the *Regulations of the Administrator*, and recent amendments to the regulations comprise the first 66 pages. The pilot written examination, questions on the regulations, and an answer key to the questions are covered in the next 14 pages. The final section is a reprint of *Fundamentals of Elementary Flight Maneuvers* (*Civil Aeronautics Bulletin No. 32*).

MANAGEMENT & FINANCE

The Executive at Work. Melvin T. Copeland. Cambridge, Mass., Harvard University Press, 1951. 278 pp. $3.75.

Based upon the author's wide experience in analyzing concrete problems in business administration, this book is a realistic account of the basic elements in administrative leadership. The executive's authority, the selection and coaching of administrative lieutenants, keeping informed, keeping the wheels turning, survival in a changing world, the spirit of risk-taking, timing, nurturing morale, extracurricular activities, standards of conduct, rewards for management, providing for retirement, and freedom for achievement are the topics discussed. The author is Director of Research and George Baker Professor of Administration at the Graduate School of Business Administration, Harvard University.

Frontiers of Personnel Administration. (1951 Conference on Industrial Personnel, Columbia Industrial Reports, 1951 Series, No. 1.) New York, Columbia University, Department of Industrial Engineering, 1951. 151 pp. $12.50.

Contents: Report on the Member-Centered Conferences, Chris Argyris and Graham C. Taylor. Executive Development in the Personnel Function, Jackson Martindell. Executive and Supervisory Training and Development, Thomas H. Nelson. Communications and Personnel, Lyman Bryson. Communications Programs—A Technique for Basic Planning. William Exton, Jr. Flexibility and Tolerance in Labor Relations Systems, Irving Lorge. Worker Participation on Production Problems, George P. Shultz. The Budgeting of Industrial Personnel, David N. Edwards. The Place and Future of Personnel, Robert Teviot Livingston. Personnel and the Community, William W. Waite. The industrial personnel bibliography at the end (pp. 125–151) lists over 800 references classified under 23 subjects.

MAPPING

Down to Earth: Mapping for Everybody. David Greenhood. New York, Holiday House, 1951. 262 pp., illus., maps. $5.00.

This is a revised third printing of an excellent popular book on the interpretation and use of maps and on map making. It was originally issued in 1944. The present printing includes various revisions accounting for changes in cartographic practice and in the names of government and private mapping agencies. The bibliography has been brought up to date.

MATERIALS

Aircraft Materials and Processes. George F. Titterton. 4th Ed. New York, Pitman Publishing Corporation, 1951. 359 pp., illus., diagrs. $5.00.

This standard book was first published in 1937 and was last revised in 1947. The present edition contains new material on military specifications, corrosion- and heat-resistant steel for jet tailpipes and a new chapter of three pages on Titanium and Its Alloys. The author is Assistant Chief Engineer of the Grumman Aircraft Engineering Corporation.

Corrosion Guide. Erich Rabald. New York, Elsevier Publishing Company, Inc., 1951. 629 pp., diagrs. $12.50.

There is a brief introduction (pp. 3–48) on the choice of materials for avoiding corrosion, principles of corrosion, measurement of corrosion resistance, and hints on using the tables. The physical properties of about 40 materials are given in a table of about ten pages. The main part of the book consists of corrosion tables (pp. 60–605) arranged according to corroding agents from acetaldehyde to zinc sulphate and indicating their effects upon the 40 types of materials by a system of symbols. Additional notes are included in numerous cases. The materials include aluminum (99.5 per cent), aluminum-silicon alloys with 12–13 per cent Si, three common types of stainless steels, chrome-nickel steels, chrome-aluminum-silicon and chrome-molybdenum steels, chrome-nickel alloys, Stellite, ceramic plates, various plastics, glass, rubber, and textiles. The bibliography includes about 57 books and the titles of over 200 journals. The author is Director and Chief Chemist of C. F. Boehringer & Söhne G.m.b.H., Mannheim-Waldhof, Germany.

Stainless Iron and Steel. Volume I, Stainless Steels in Industry. J. H. G. Monypenny. 3rd Ed., Revised. London, Chapman & Hall, Ltd., 1951. 524 pp., illus., diagrs. 45*s*.

This outstanding treatise was last revised in 1931. The present edition will be in two volumes, of which this is the first. The second volume will deal with Microstructure and Constitution; therefore little is said in the present volume on metallography. The stainless steels in commercial use are described in the first chapter, including hardenable and ferritic stainless steels and particularly (pp. 50–145) nonhardenable austenitic stainless steels. The effects of industrial processes on stainless steels are discussed in the second chapter, followed by detailed consideration of their corrosion-resisting properties. Behavior at High Temperatures and Selection of Stainless Steels for Industrial Purposes are the final two chapters, which include a discussion of the internal combustion turbine. Footnote references are included throughout, and there are indexes of authors and subjects.

Stainless Steel Handbook. Pittsburgh, Allegheny Ludlum Steel Corporation, 1951. 120 pp., diagrs.

MEDICINE

The Perception of the Visual World. James J. Gibson. Boston, Houghton Mifflin Company, 1950, illus., diagrs. $4.00.

Based partly upon research in the field of military aviation during World War II, this book emphasizes the physics of perception rather than the physiology. It is based upon ideas of Gestalt psychology, American functionalism, and dimensionalism as studied by such psychologists as Kurt Koffka, Leonard T. Troland, and Edwin G. Boring. The author's purpose is to formulate a consistent approach to the visual perception of space as a solution to the basic problem of all perception, since space perception is inseparable from time. There is a bibliography of 121 references. Dr. Gibson was engaged in research with the U.S. Air Force during World War II and is now a Professor of Psychology at Cornell University.

Space Medicine, the Human Factor in Flights Beyond the Earth. Edited by John P. Marbarger. Urbana, University of Illinois Press, 1951. 83 pp., illus., diagrs. $3.00.

Contents: Space Medicine in the United States Air Force, Major General Harry G. Armstrong. Multi-Stage Rockets and Artificial Satellites, Werner von Braun. Physiological Considerations on the Possibility of Life Under Extraterrestrial Conditions, Hubertus Strughold. Astronomy and Space Medicine, Heinz Haber. Orientation in Space, Col. Paul A. Campbell. Bioclimatology of Manned Rocket Flight, Konrad Buettner.

Decompression Sickness: Caisson Sickness, Diver's and Flier's Bends and Related Syndromes. Compiled Under the Auspices of the Subcommittee on Decompression Sickness, Committee on Aviation Medicine, National Research Council. Philadelphia, W. B. Saunders Company, 1951. 437 pp., illus., diagrs. $8.50.

The results of studies by the Subcommittee on Decompression Sickness, established in 1942 by the Division of Medical Sciences of the National Research Council at the request of the U.S. Armed Forces, are presented in 13 papers. The bibliography lists 545 references, including 309 published papers and about 236 unpublished research reports of the National Research Council Committee on Aviation Medicine, the U.S. Navy, the U.S. Air Force, Canadian reports, reports of the British Flying Personnel Research Committee, the Medical Research Council of Great Britain, and German Air Force research.

Contents: Historical Introduction, John F. Fulton. The Clinical Nature of High Altitude Decompression Sickness, Eugene B. Ferris, Jr., and George L. Engel, with a Note on Psychologic Reactions by John Romano. Decompression Sickness Following Exposure to High Pressures, Albert R. Behnke. Physical Factors in Bubble Formation, E. Newton Harvey. Animal Experiments on Bubble Formation, Part I, Bubble Formation in Cats, E. Newton Harvey. Part II, Bubble Formation in Frogs and Rats, L. A. Blinks, V. C. Twitty, and D. M. Whitaker. Decompression Sickness: Physical Factors and Pathologic Consequences, Isidore Gersh and Hubert Catchpole. Constitutional Factors Affecting Susceptibility to Decompression Sickness, John S. Gray. Environmental Factors Affecting Decompression Sickness, Part I, A Physical Theory of Decompression Sickness, Leslie F. Nims. Part II, Role of Exercise, Temperature, Drugs and Water Balance in Decompression Sickness, S. F. Cook. Preoxygenation and Nitrogen Elimination, Part I, Review of Data on Value of Preoxygenation in Prevention of Decompression Sickness, J. B. Bateman. Part II, Gas Exchange and Blood-Tissue Perfusion Factors in Various Body Tissues, Hardin B. Jones. Preselection Tests, Franklin M. Henry and A. C. Ivy. Decompression Sickness in Actual Flight, C. A. Tobias. Explosive Decompression, Fred A. Hitchcock.

METEOROLOGY

Weather Control and Augmented Potable Water Supply. Joint Hearings Before Sub-Committees of the Committees on Interior and Insular Affairs, Interstate and Foreign Commerce, and Agriculture and Forestry, United States Senate, 82nd Congress, 1st Session. Washington, U.S. Govt. Printing Office, 1951. 353 pp.

NAVIGATION

Human Engineering for an Effective Air-Navigation and Traffic-Control System. Edited by Paul M. Fitts. A Report Prepared for the Air Navigation Development Board by the Ohio State University Research Foundation Under the Auspices of the N.R.C. Committee on Aviation Psychology. Washington, National Research Council, March 1951. 84 pp., illus.

Proposals are submitted for a long-range program of human engineering research on the problems of planning and designing equipment for an air-navigation and traffic-control system. The essential functions of the air-traffic control system

are outlined, and the question of which functions should be automatic and which should be performed by human operators is considered. The present state of knowledge of human capabilities is reviewed as they relate to air-traffic control problems, and applications of research findings are discussed. A detailed future research program is suggested. A survey of the opinions of 60 air-traffic controllers and tower controllers on bottlenecks, human and automatic operations, and equipment desirable is included. There is a glossary and a list of about 100 references. The report was prepared under a contract to the National Research Council by the C.A.A. and was prepared by psychologists of eight university and two Air Force psychology laboratories.

PRODUCTION

Production Control. Franklin G. Moore. New York, McGraw-Hill Book Company, Inc., 1951. 455 pp., illus., diagrs. $5.50.

This textbook describes current practices in production control considered to involve the transmission of information, the authority to perform operations, and the capability of checking on the performance of these operations. Considerable attention is given to order control, and there are separate chapters on flow control, block and load control, mechanical tabulation, and reproduction of forms and communications systems. About 70 study problems are included, and a bibliography of about 30 books. The author is associated with Northwestern University.

Welding Principles for Engineers. Joe Lawrence Morris. New York, Prentice-Hall, Inc., 1951. 511 pp., illus., diagrs. $7.00.

This textbook is intended for the engineering college student. It covers welding metallurgy, all welding processes, testing and inspection of welds, the welding of commercial metals, braze welding, brazing and soldering, surfacing, metal spraying filler materials, flame heat-treatment, oxygen cutting, stress and distortion, design for welding, and factors affecting welding production economy. Bibliographies are given at the ends of chapters, but laboratory exercises are not included. The author is an Assistant Professor in the School of Mechanical Engineering at the Georgia Institute of Technology.

Industrial Piping. Charles T. Littleton. R. A. Dickson. New York, McGraw-Hill Book Company, Inc., 1951. 394 pp. illus., diagrs. $8.00.

The author's purpose is to present information in convenient form on the design and installation of piping systems as required by the chemical and process industries. Steam, water, oil, gas, air, and instrument piping are included, with separate chapters on valves, alloy piping, piping materials, and insulation. In the final chapter on Estimating Piping Costs by R. A. Dickson, a system is presented which is based on the constant ratio of the costs of pipe of various sizes in the same material. Numerous data tables and drawings of fittings are included throughout.

REFERENCE WORKS

German-English and English-German Dictionary for Scientists. O. W. Leibiger and I. S. Leibiger. Petersburg, N.Y., O. W. Leibiger Research Laboratories, Inc., 1950. 741 pp. $8.00.

About 90,000 German terms and their English equivalents in the fields of chemistry, physics, mathematics, engineering, aeronautics, dynamics, biology, physiology, medicine, and other sciences are given. The authors' primary fields of interest, chemistry and physics, respectively, ensure adequate coverage of basic scientific terms. Their practical experience in translating German technical literature, including numerous documents of World War II, is evident in their inclusion of numerous terms relating to new developments in aircraft propulsion and design. Theoretical terms are liberally included, such as interface phenomena, body of revolution, nonlinearity, rheological, axial load, helical vortex, elasticity modulus, and boundary-layer control.

RCA Technical Papers (1946–1950), Index, Volume II. Princeton, N.J., RCA Review, Radio

Corporation of America, RCA Laboratories Division, 1951. 95 pp.

About 1,022 papers are listed in this supplement to Volume I (1919–1945); the two lists cover 2,801 papers. There is an index of authors and an index arranged under broad subjects, such as communications or propagation. The titles of papers are listed in chronological order, then in alphabetical order, with the reference to the journal and its date of issue included in each list.

Chamber's Dictionary of Scientists. A. V. Howard. New York, E. P. Dutton and Company, Inc., 1951. 499 pp., illus. $10.

Brief biographies of approximately 5,700 scientists and engineers from all fields and all periods are included in this reference work. Living scientists are included. Aeronautical names included are Archytas, Leonardo da Vinci, Samuel P. Langley, Sir Frank Whittle, and Wilbur Wright. Among the omissions are Sir George Cayley, Octave Chanute, and Frederick Lanchester. The biographies are excellent within their scope, especially those of Ernst Mach and Wilbur Wright. There is an index of subjects. The author's selections necessarily cover only landmarks in scientific development.

Directory of Members, 1951. New York, Special Libraries Association, 1951. 289 pp. $4.00.

The names and addresses are given of 4,801 individuals, cross-indexed with the names of 2,607 companies, laboratories, government agencies, universities, and libraries with which they are connected.

SCIENCES, GENERAL

MATHEMATICS

Integral Transforms in Mathematical Physics. C. J. Tranter. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1951. 115 pp. $1.50.

The author's purpose is to outline the procedure for the use of an integral transform in the solution of boundary-value problems. Following an introductory chapter on Integral Transforms and Their Inversion Formulae, the Laplace Transform, Fourier Transforms, and Hankel and Mellin Transforms are discussed. The Numerical Evaluation of Integrals in Solutions is discussed next, including the Willis method using asymptotic series and Filon's method for trigonometric integrals. The procedures of previous chapters are applied to finite transforms, and the final chapter deals with The Combined Use of Relaxation Methods and Integral Transforms. The bibliography refers to 18 books and 48 original papers. The author is Associate Professor of Mathematics at the Military College of Science in Shrivenham.

Introduction to Modern Algebra and Matrix Theory. O. Schreier and E. Sperner. Translated by Martin Davis and Melvin Hausner. New York, Chelsea Publishing Company, 1951. 378 pp. $4.95.

This is a translation of the authors' *Einführung in die Algebra und analytische Geometrie* (Leipzig, 1931–1937, 2 vols.). A final chapter of the original work, dealing with projective geometry, is omitted. Chapter 5, Linear Transformations and Matrices, includes adaptations from the authors' earlier monograph *Vorlesungen über Matrizen*. The first four chapters deal with Affine Space and Linear Equations, Euclidean Space and the Theory of Determinants, Field Theory, and Elements of Group Theory.

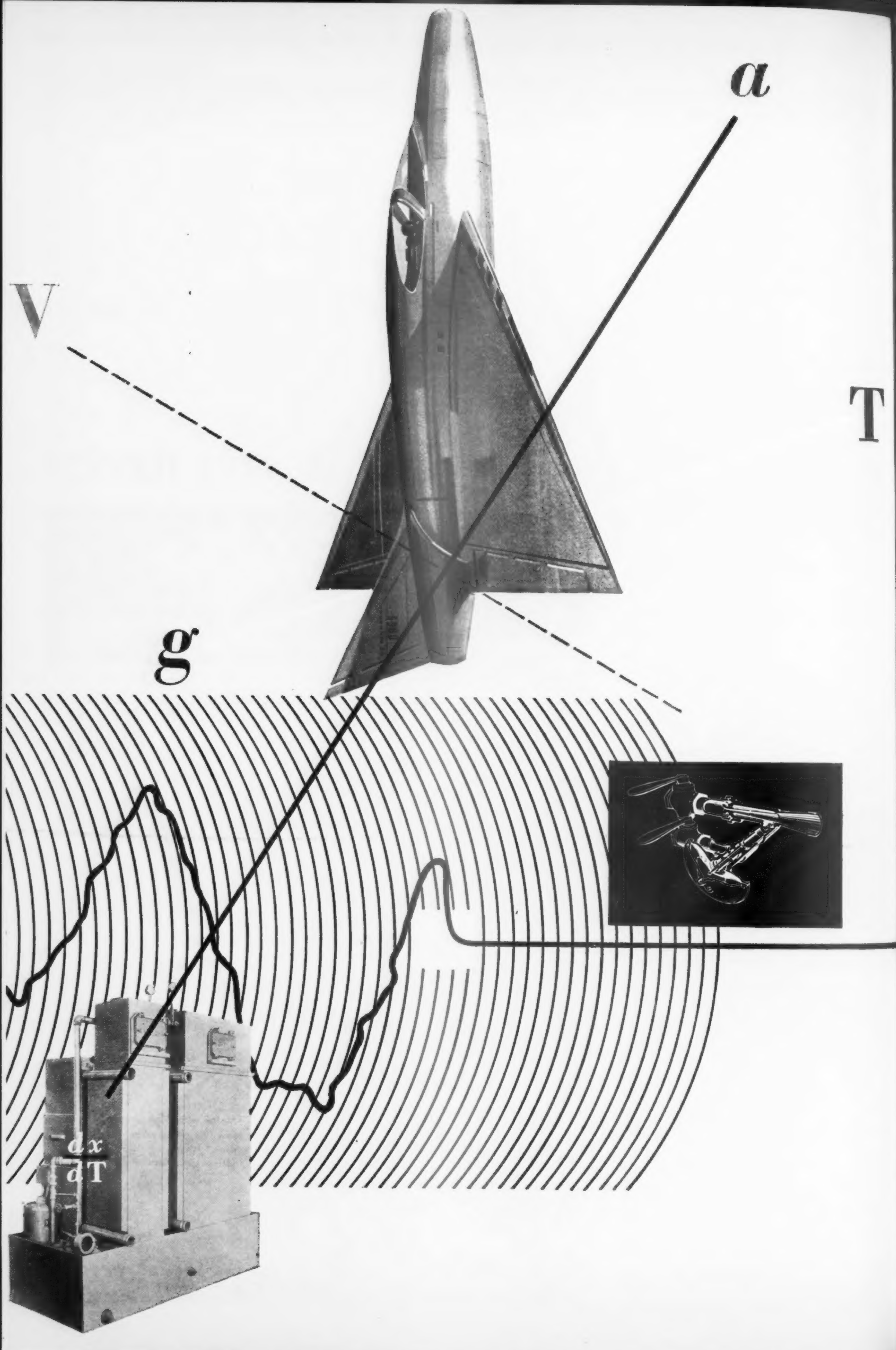
Engineering Graphics. John T. Rule and Earle F. Watts. New York, McGraw-Hill Book Company, Inc., 1951. 298 pp., illus., diagrs. $3.75.

The authors' aim is to present a formal course in graphics covering the basic theories of both the analytic and representational sides of graphics as taught in elementary courses in engineering drawing at the Massachusetts Institute of Technology. The purpose is to make the engineering student competent in the graphic solution of engineering problems, so that he can apply algebraic, numerical, or graphic methods as the case requires. Manual skill in the use of drawing equipment is acquired in the process. The chapters on geometric constructions, conic sections, projective geometry, and vectors are concerned with problems and ideas of synthetic geometry. Coordinate geometry is brought into the chapters on graphic scales, empiric curves, graphic calculus, and descriptive geometry in the final chapters on orthographic projection and axonometry. The senior author is Professor and Head of the Section of Graphics, and Mr. Watts is former Associate Professor, Section of Graphics, at the Massachusetts Institute of Technology.

Mathematics for Engineers. Raymond W. Dull. Revised and Edited by Richard Dull. 3rd Ed. New York, McGraw-Hill Book Company, Inc., 1951. 822 pp., diagrs. $7.50.

This standard treatise was last revised in 1941. Two new chapters have been added on Differential Equations and Dimensional and Similarity Analysis. New material and examples have been added to various chapters. New material includes expansions in hyperbolics and algebraic operations in the discussion of infinite series, multiplication of determinants applied to matrix theory, geometric relationships of the circular functions in the discussion of trigonometric functions, complex vectors with regard to periodic functions in the discussion of coordinates in the geometry of three dimensions, and a graphic analysis of the hyperbolic functions. The chapters on numerical computations with algebraic aids, absolute relative errors, implicit quadratic equations with graphs, fundamental differentiation, and differentiation of algebraic functions have been deleted or incorporated into other chapters.

Table of Arctangents of Rational Numbers. John Todd. (U.S., National Bureau of Standards, Applied Mathematics Series No. 11.) Washington, Supt. of Documents, 1951. 105 pp. $1.50.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PHYSICS

Theoretical Physics. Georg Joos, with the Collaboration of Ira M. Freeman. 2nd Ed. New York, Hafner Publishing Company, 1951. 853 pp., illus., diagrs. $8.25.

This text and reference book was first issued in German in 1932 and translated into English in 1934. The present translated edition is larger by more than 100 pages. A new section of selected topics from technical fields has been added, including applications of the geometric optics of light and of electrons, piezoelectricity, and space-charge effects in gaseous discharges. A mathematical section has been added on the properties of Bessel functions and spherical harmonics. Chapter 41 on Nuclear Physics has been extended, with separate new sections on the neutron, the positron, artificial radioactivity, the role of protons and neutrons in nuclear structure, fission of the heavier nuclei, beta transformations, the meson, and a brief survey of cosmic rays. Discussions of electrocaloric and magnetocaloric phenomena and the unattainability of the absolute zero are added to chapters on heat, and a discussion of the elastic potential is added to the chapter on elasticity. Professor Joos teaches experimental physics at the Technische Hochschule in Munich, and Dr. Freeman is Associate Professor of Physics at Rutgers University.

The Restless Universe. Max Born. 2nd Ed. Authorized Translation by Winifred M. Deans. New York, Dover Publications, Inc., 1951. 315 pp., illus., diagrs. $3.95.

This readable account of modern physics was first published in 1936. The present edition includes a postscript of 36 pages dealing with developments of the last 15 years. The original chapters are the same: The Air and Its Relatives, Electrons and Ions, Waves and Particles, The Electronic Structure of the Atom, and Nuclear Physics.

STRUCTURES

Strength of Materials. Glen N. Cox, Frank J. Germano, and John H. Bateman. New York, Pitman Publishing Corporation, 1951. 408 pp., illus., diagrs. $5.50.

This textbook is designed for a first course for engineering students who have completed a course in statics. Recent experimental results are taken into account in the treatment of such topics as riveted joints, column action, repeated stress, and stress concentration. The theorem of three moments is included in the chapter on statically indeterminate beams, but the moment distribution method is outlined in a special appendix. Over 500 problems of graded difficulty are included. The senior author is a Professor of Hydraulics and Mechanics at New York University. Professor Germano teaches engineering mechanics, and Professor Bateman teaches civil engineering at Louisiana State University.

Pressure Vessels; A Simple and Practical Approach to Their Design and Certification. (Mechanical World Monographs, No. 58.) William Buchan Ritchie. Manchester, England, Emmott & Company, Ltd., 1950. 71 pp., diagrs. 3s.

The author aims to present, in everyday language, methods for the choice and correct application of the existing British rules for the design of all types of pressure vessels, based on fundamental laws of mechanics. Plain thin cylindrical shells, design of ends of the vessel and the effects of openings, thin cylinders exposed to external pressure, rectangular flat plates and their reinforcements, effects of elevated temperatures, hydrostatic tests, properties of various materials, and operational precautions are among the topics discussed.

TECHNICAL WRITING

The Scientific Paper, How To Prepare It, How To Write It. Sam F. Trelease. 2nd Ed. Baltimore, The Williams & Wilkins Company, 1951. 163 pp., diagrs. $2.50.

This excellent manual was last revised in 1947. The material has been rearranged in the present

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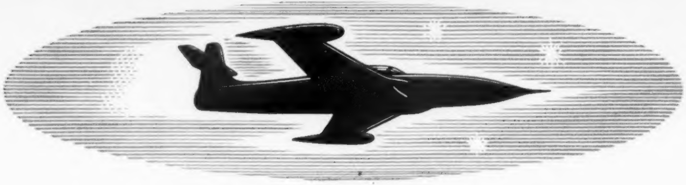

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edition and expanded. The Research Problem is covered in the first chapter, including procedures in collecting data and first steps in organizing and evaluating the material. Detailed chapters follow on Writing the Paper and Good Form and Usage. Tables and Illustrations are discussed in separate chapters, and the book ends with discussions of prepublication review and proofreading. There is a bibliography of about 50 books. The author is associated with Columbia University.

THERMODYNAMICS

Gas Turbine Plant Heat Exchangers, Basic Heat Transfer and Flow Friction Design Data. W. M. Kays, A. L. London, and D. W. Johnson. New York, American Society of Mechanical Engineers, April 1951. 74 pp., diagrs. $3.00.

The authors' purpose is to present under a single cover a summary of the basic design data obtained by two programs of research on heat transfer and friction flow upon compact surfaces, carried out at the Naval Engineering Experiment Station in Annapolis and at Stanford University. A common treatment is given for all data. Results are given for 34 different surfaces of varying surface geometry, including tubes, plain fins, louvered fins, strip fins, ruffled fins, pin-fins, and finned-flat-tube surfaces. The research was carried out under the sponsorship of the Office of Naval Research, Bureau of Ships, and the Bureau of Aeronautics, and the present report is issued under the auspices of the Gas Turbine Power and Heat Transfer Divisions of the A.S.M.E. There is a bibliography of 25 original reports. The authors are, respectively, Instructor, Professor, and Graduate Student in mechanical engineering at Stanford University.

Erratum

Through a typographical error in the July, 1951, issue of the REVIEW, page 106, the price of *Ordnance Production Methods*, edited by Charles O. Herb, was given as $1.00. The corrected reference is as follows.

Ordnance Production Methods. Edited by Charles O. Herb. New York, The Industrial Press, 1951. 534 pp., illus. $10.

Aeronautical Reviews

(*Continued from page 114*)

An Investigation of Aircraft Heaters. XXXV—Thermocouple Conduction Error Observed in Measuring Surface Temperatures. L. M. K. Boelter and R. W. Lockhart. *U.S., N.A.C.A., Technicle Note No. 2427*, July, 1951. 34 pp., illus. 5 references. Study of the measurement error introduced by conduction of heat along the thermocouple wire; experimental results.

Water-Borne Aircraft (21)

Boat Beacher. *Aviation Week*, Vol. 55, No. 6, August 6, 1951, pp. 32, 37, illus.

Model 144 self-propelled gear for beaching flying boats was developed by Edo Corp. The gear consists of two vertical floatation units spaced to accommodate the hull of a flying boat; a horizontal platform has a removable pallet with adjustable pillows on which the hull rests.

Wind Tunnels & Research Facilities

Design and Research. *Aviation Age*, Vol. 16, No. 1, July, 1951, pp. 35–37, illus. Soviet research facilities and trends.

Defense Department Plans for Basic Research. Harold A. Zahl, E. R. Piore, and J. W. Marchetti. *Electronics*, Vol. 24, No. 8, August, 1951, pp. 82–87, illus.

Prospects for the continuance of basic electronics research; military contracts; man power policies of the Army, Navy, and Air Force; research facilities; coordination of research efforts by the Department of Defense.

Wind-Tunnel Tests of a $^1/_{12}$-Scale Model of Towing Dynamometer No. 5. *U.S., Navy Department, David W. Taylor Model Basin, Report No. R-344*, April, 1951. 8 pp., illus.

Summary of Recent Experimental Investigations in the N.O.L. Hyperballistics Wind Tunnel. Peter P. Wegener. *Journal of the Aeronautical Sciences*, Vol. 18, No. 10, October, 1951, pp. 665–670, 682, illus. 13 references.

Research program and facilities for studying hypersonic flow ($M > 5$). Details are given of the 12- by 12-cm. hyperballistic tunnel. The research program is mainly concerned with the physical problems of air condensation, Mach Number determination, effect of temperature on tunnel operation, boundary layers, and instrumentation. Some measurements of boundary layer and flow separation are reported.

Aerodynamic Methods Applied to Turbo-Machine Research. J. Lalive d'Epinay. *Brown Boveri Review*, Vol. 37, No. 10, October, 1950, pp. 357–367, illus. 9 references.

Research facilities at Brown, Boveri, and Co., Ltd., Switzerland, for design and performance studies on axial-flow compressors include a supersonic wind tunnel, schlieren apparatus, a water canal, a profile projector for studying blade shapes, and the associated compressor and turbines for driving the test equipment.

Application of X-Ray Absorption to Measurement of Small Air-Density Gradients. Ruth N. Weltmann, Steven Fairweather, and Daryl Papke. *U.S., N.A.C.A., Technical Note No. 2406*, July, 1951. 41 pp., illus. 2 references. Analysis of two X-ray absorption method (one method uses a Geiger-Mueller counter for detection and the other uses photographic film); accuracy and sensitivity.

Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and organizations offering employment to Aeronautical specialists. Any member or organization may have requirements listed without charge by writing to the Secretary of the Institute.

Wanted

Physicist, Electrical or Mechanical Engineer—Graduate engineer for design, development, and testing of flight-test instrumentation. Must be capable of electronic design work associated with servosystems, strain gage measuring circuits, and other type instruments used in flight testing. Mechanical knowledge must be sufficient to lay out installation of test equipment in airplanes and design mechanical test equipment for instrument calibration work in laboratory. One or more years of experience with background of aeronautical engineering work desirable but not essential. Address replies to Dept. AER 8, Cornell Aeronautical Laboratory, Inc., 4455 Genesee Street, Buffalo 21, N.Y.

Instrument Engineers—Two or 3 years' experience in pressure sensitive instruments and small precision mechanisms, experimental and preliminary design work, regular products. Excellent working conditions. Résumé requested. Location, New Jersey suburban area. Wallace & Tiernan Products, Inc., 1 Main Street, Belleville, N.J.

Electronics Instrumentation Engineer—B.E.E. or B. Physics degree required with additional graduate work preferred. Minimum of 5 years of experience. This is a permanent position in charge of an electronics laboratory associated with an aeronautical laboratory. There also are some openings for electrical engineers with less experience. Salary is commensurate with experience. Graduate privileges are available. Liberal employee benefits. Housing not a pressing problem. Send letters of application to: University of Minnesota, Department of Aeronautical Engineering, Rosemount Research Laboratories, Rosemount, Minn.

Research Engineers, Aeronautical and Mechanical Engineers, Specialists in Applied Mechanics—Permanent opportunities in research and development including mechanical design aeroelastic research, static and dynamic measurements, applied mathematics, engineering structures, and dynamic analysis. Industrial as well as military programs. Salaries in accordance with ability and experience. Located deep in the heart of Texas on the 4,000-acre Essar Ranch. Address replies to: C. D. Pengelley, Chairman, Engineering Mechanics Department, Southwest Research Institute, P.O. Box 2296, San Antonio, Tex.

Flutter Engineer—Permanent position for experimental and theoretical research in flutter, vibration, aeroelasticity, and dynamic loading. Two to 5 years' experience required. Salary commensurate with ability. Unique opportunity to join rapidly developing research organization located on the beautiful Essar Ranch. Address replies to: C. D. Pengelley, Chairman, Engineering Mechanics Department, Southwest Research Institute, P.O. Box 2296, San Antonio, Tex.

Process-Standard Unit Chief—Opening for experienced man to supervise the operations of a unit involved in production and research in the Boeing B-47 jet bomber program for the Air Force. This includes work in the fields of standards, chemical, metallurgical, and mechanical processes; plastics, adhesives and sealers; and drafting procedures. Must be engineering graduate, preferably in chemistry, metallurgy, or aeronautics, with a minimum of 10 years' experience in this field, of which at least 5 years must be in the aircraft industry. Must have had supervisory experience. Write for application blank or submit personal history including education, work experience, and references to our Administrative Engineer. Boeing Airplane Company, Wichita, Kan.

Aerodynamics Master Engineer—T.W.A. has an immediate opening for a master engineer having a rich, practical, and theoretical background in aerodynamics. Desire candidate with 2 to 3 years of actual manufacturing or air-line experience, with background in jet propulsion and related aerodynamics problems. Starting salary $5,790 plus free passes and other desirable employee benefits. Write full qualifications to: Wilbur L. Stone, Employment Manager, Trans World Airlines, 10 Richards Road, Kansas City 6, Mo.

350. Instructor or Assistant Professor—An opening is available immediately for Instructor or Assistant Professor to teach either aerodynamics or structures courses at a leading engineering college in the East. Salary and rank commensurate with experience and background. Some industry experience and advanced degree desired.

The number preceding the notices represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

Available

353. Mechanical and Aeronautical Engineer—B.S., M.E. Available for consultation. Experience includes: design and development of variety of automotive devices; patent analysis and patent expert in important litigation; design, development, and test supervision of well-known helicopter; study and design of convertoplane; origination and development of intricate ordnance mechanisms.

352. Aeronautical Engineering Professor-Development Engineer (M.S.)—Extensive and varied aeronautical background (both administrative and technical) in fixed and rotating wing aircraft. Graduate and undergraduate teaching experience in aerodynamics (classical and supersonic), design, and structures. Many aeronautical publications including textbook. Will consider research and administrative possibilities.

351. Aeronautical Engineer—Age 33. Two years' postwar light aircraft and accessory sales experience. Four years' service in Army Air Forces. Air Transport Command Dispatcher. Two years' Army Air Forces Intelligence in Air Materiel Command. Graduate 1st A.A.F. Helicopter Maintenance Engineering training unit. One year of aeronautical drafting, 6 months' air-line experience.

349. Technical Training Administrator—Ten years of experience in administration technical training schools, including personnel, equipment, and outlines of instruction. Have also had extensive "on-the-job training" experience. Age 41. Further details on request.

347. Aeronautical Draftsman—B.Sc., B.E., Cert. in Aero. Drafting and Engineering. Desires position as draftsman, layout, design, or detail; experience includes 10 years as Engineering Draftsman, 5 years as Drafting Instructor. Foreign citizen, but would undergo any security investigation in order to obtain clearance. Location preferred: eastern states.

345. Teaching—Ph.D. in Aero. Eng. Twelve years' experience in theoretical research and teaching. Desires to teach fluid and solid mechanics, aerodynamics, and applied mathematics at graduate level, with some sponsored research. Rank of Associate Professorship will be agreeable.

344. Aeronautical Engineer—With over 10 years' experience supervising design, development, and testing of high-speed aircraft. Desires position as Chief Preliminary Design Engineer, responsible for organizing development and proposal work. Excellent references. Eastern location preferred.

343. Pilot Engineer—M.S. in Aeronautical Engineering, 1951. Nine months Liaison Engineer; 1 year Flight-Test Analysis Lead Engineer. Commercial Pilot, 9 years, Instrument, Instructor, single- and multiengine land. Two thousand three hundred and fifty hours—1,051 single-engine, 1,300 multiengine. Seventy hours of stability and performance testing. Interested in obtaining a position involving test flying.

342. Administrative Engineer—Assistant to Executive—Fifteen years of varied experience in aviation and electronics. Presently with Navy research organization planning and conducting far-reaching investigations into advanced aircraft instrumentation. Previous experience in industrial and aviation electronics (Head, Control Laboratory, Lear, Inc.); Aircraft Ignition (Assistant Chief Engineer, Aero Spark Plug); Gas-Turbine Controls (Chief, Control Section, Fredric Flader, Inc.). Lecturer to instrument, aviation, and aeromedical groups on specialized man-machine aviation problems. Seeks supervisory or administrative position. Salary, $9,000.

337. Pacific Coast Representative—Internationally known aeronautical engineer with Los Angeles office will represent eastern company as sales, engineering and service, and procurement representative on Pacific Coast. Entree to all aircraft and parts manufacturers.

336. Associate Professor—Ten years' teaching and research experience in theoretical and experimental fluid mechanics. Dr. Eng. degree, several publications. Age 30. Would like to join staff of large school. No preference of location.

335. Professor of Aeronautics & Aeronautical Engineer—M.A. (Oxon), B.Sc., F.R.Ae.S., M.I.-B.E. Industrial experience in drawing, office, stress office, weight control, detail design, project office, repairs and modifications, maintenance, production, aerodynamic and structural testing and research, flight testing procedure, airworthiness, and general organization of large departments. Positions held as chief of stress, chief technician, research engineer, designer, chief airworthiness engineer. Approved design consultant. Member of various design, research, and airworthiness committees. Author of textbook and various detail design handbooks. Considerable experience in lecturing at London, Bristol, and Oxford Universities. At present, Professor of Aeronautics; responsible for inaugurating new aeronautical engineering departments in aerodynamics, structural design, and aircraft propulsion in two universities. Engaged also as government consultant to form new airworthiness and inspection departments and to design and construct a number of wind tunnels. Age 44. Replies at this stage to be confidential.

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